

Professor Playfair's lectures on natural philosophy : [handwritten lecture notes, 1818-1819]. Vol. III

Brodie, William

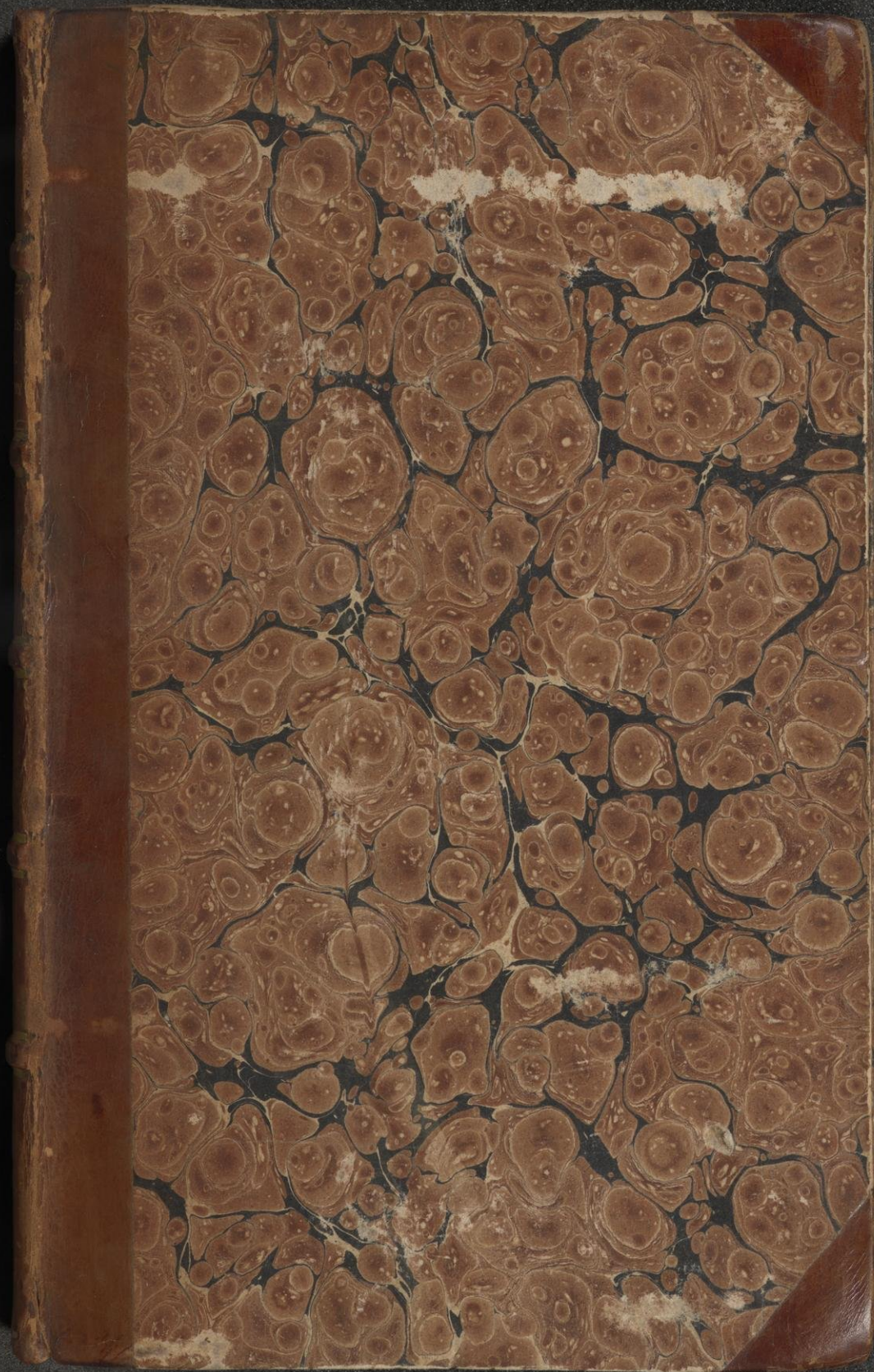
Edinburgh, Scotland: [publisher not identified], 1818

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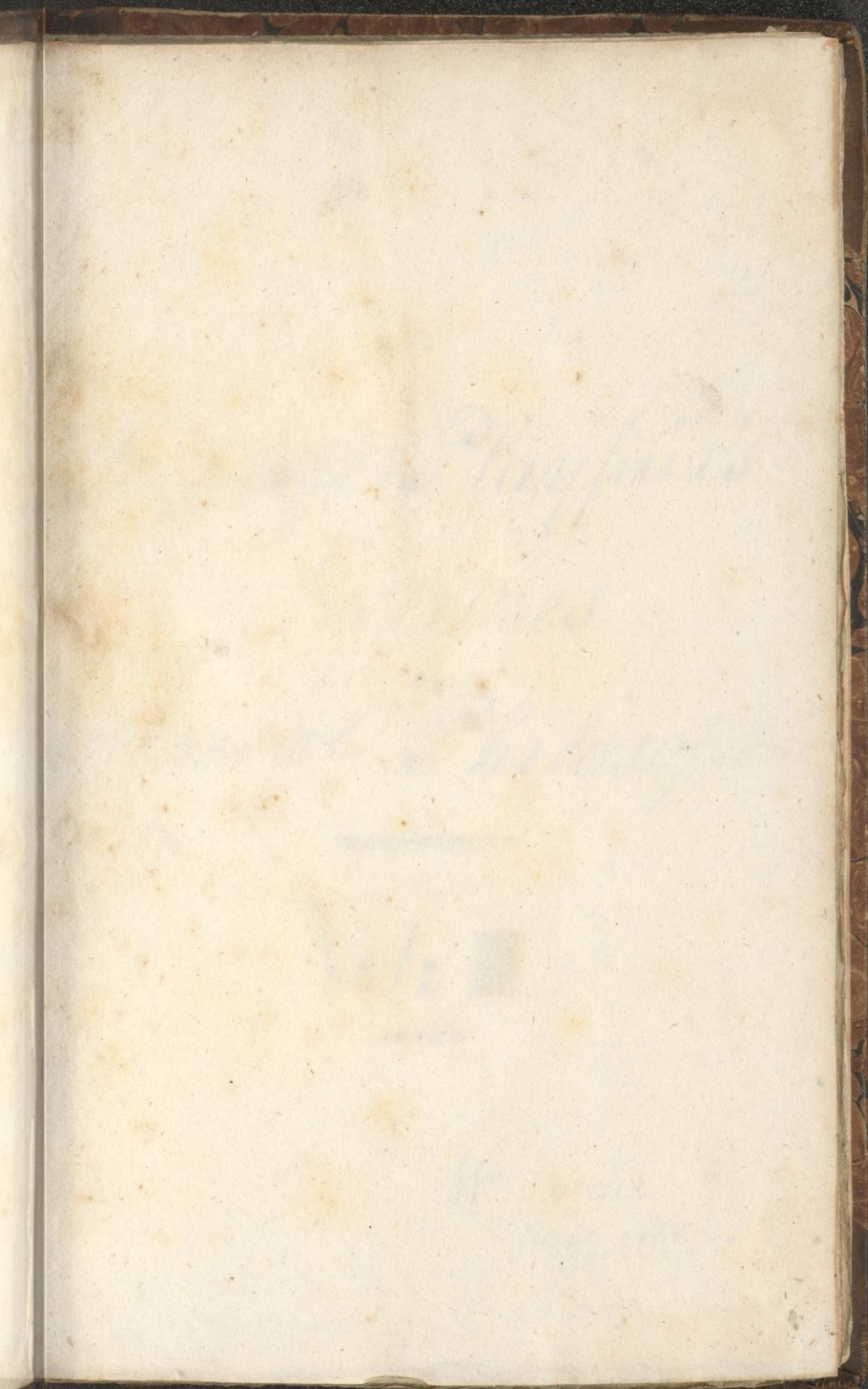
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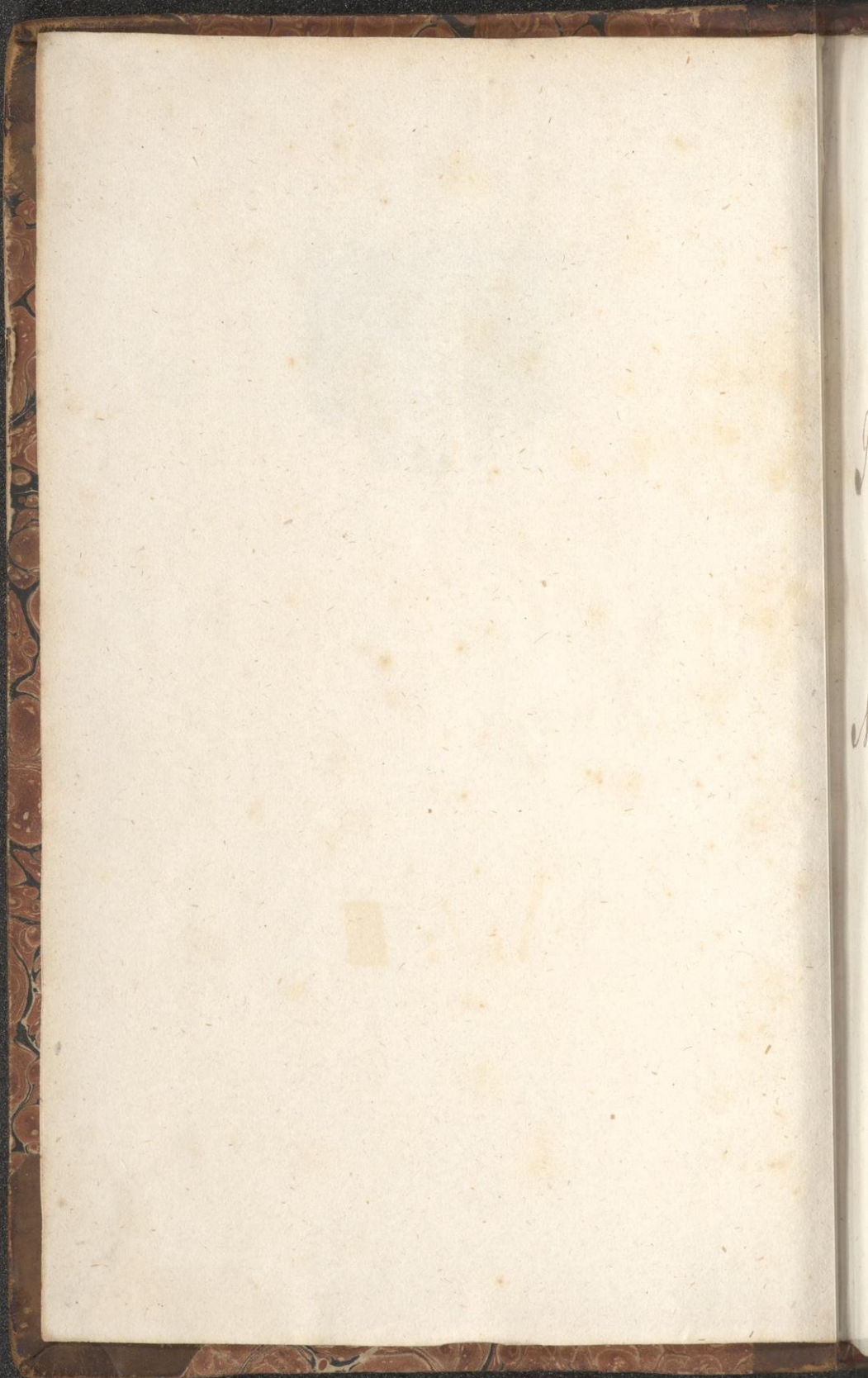
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Professor Playfair's
Lectures
on
Natural Philosophy

Vol: III

Wm. Brodie

Edin^o. 1818-19

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Professor R. Whipple

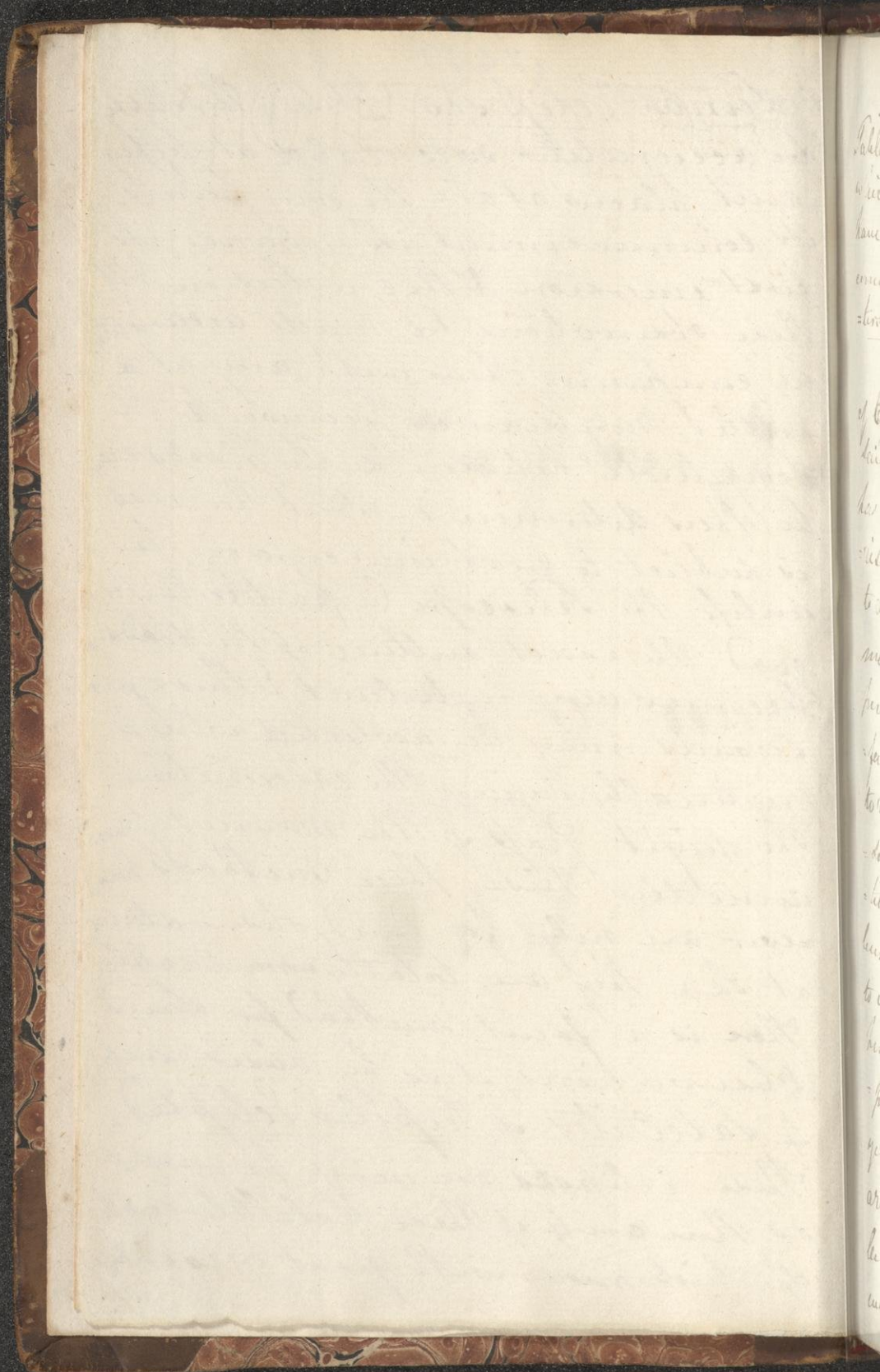
Lectures

Harvard University

Vol. I

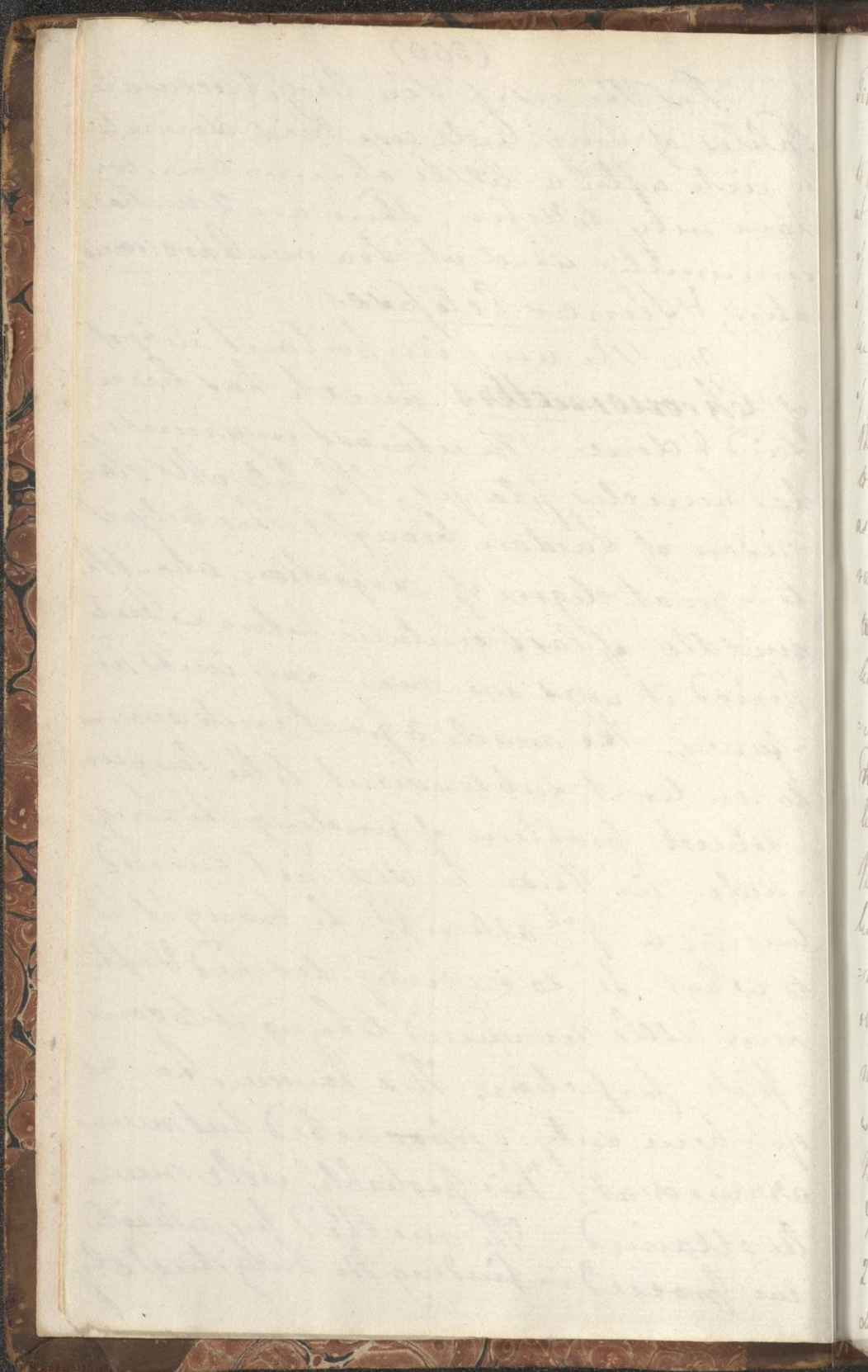
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Lunar Eclipses. Thus if the Eclipse be accurately calculated at different places at all the four points, its commencement, its entrance, its first-immerision, & the conclusion. If these observations be made accurately, by comparing them with any at a settled Meridian as Greenwich, the Longitude between such places may be thus determined - But this also is subject to great inaccuracy, for unless the Telescope be particularly good the exact outline of the shadow becomes very indistinct & thus a few seconds may be neglected which materially injure the calculation. The night Glass of the Mariner is of no use in this - These methods however are only for land observations at Sea they are totally impracticable. There is a fourth method for Land observations, it is by observing 4 Satellites of Jupiter Eclipsed. These Eclipses are very frequent as there are 4 of these Satellites each of which move with great velocity.



For the use of Sea Large Occasional
Tables of Longitude are laid down to
which after a little observation we
have only to refer. There are 2 methods
commonly used at Sea viz Chronome-
-ters & Lunar Eclipses

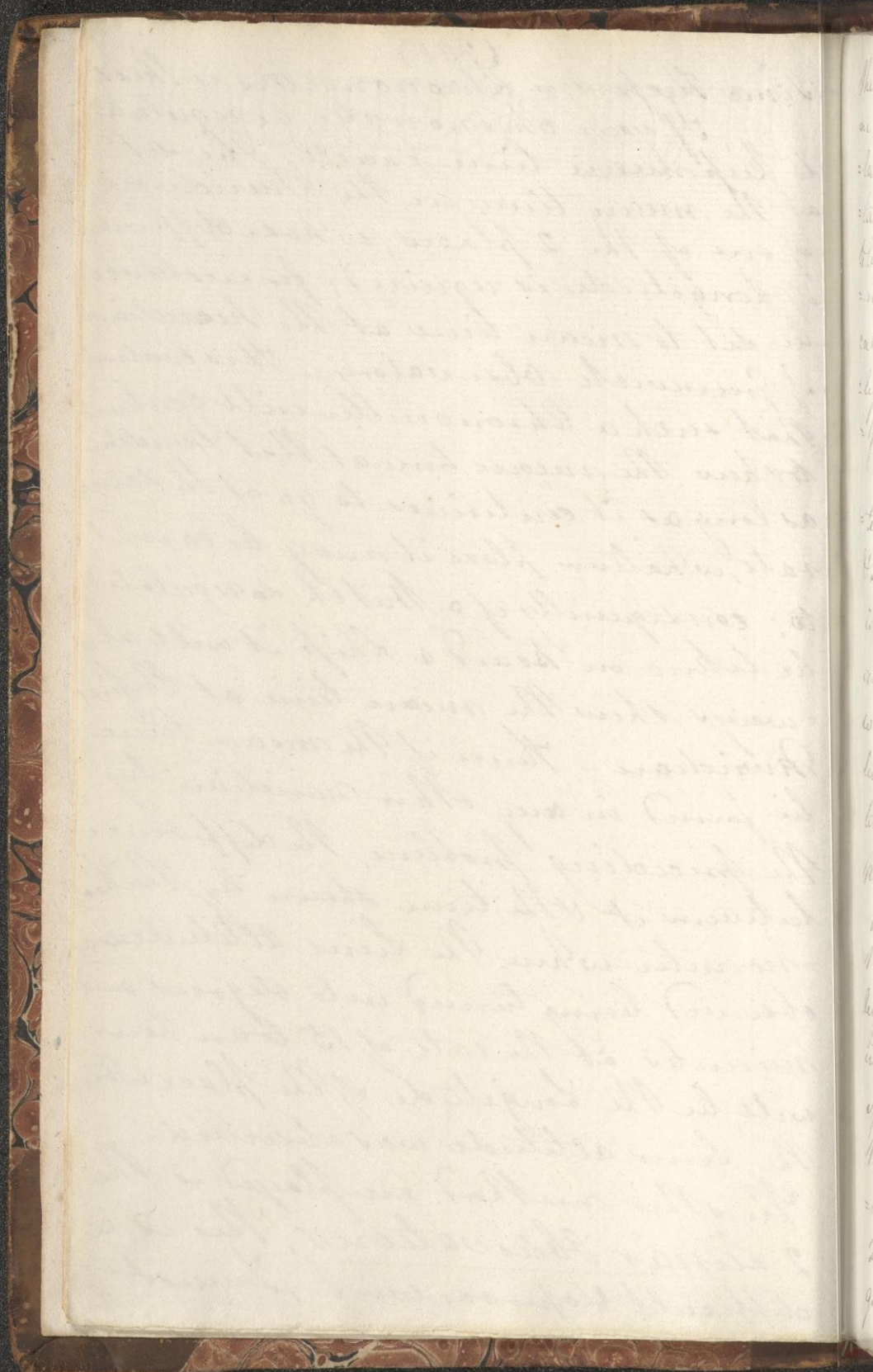
On the very important subject
of Chronometers much has been
said & done. The utmost ingenuity
has been displayed. The late Mr Har-
-rison of London brought this subject
to a great degree of perfection about the
middle of last century before which
period it was we may say in its in-
-fancy. He made 3 great endeavours
to render it subservient to the longun-
-derstand problem of finding the Longi-
-tude, in those he did not succeed
but in a 4th attempt he brought it
to what he so eagerly desired & after
him little remained to bring it to com-
-plete perfection. This however has as
yet been only approached but never
arrived at. This probably will never
be attained - The method by which
we proceed in finding the Longitude by

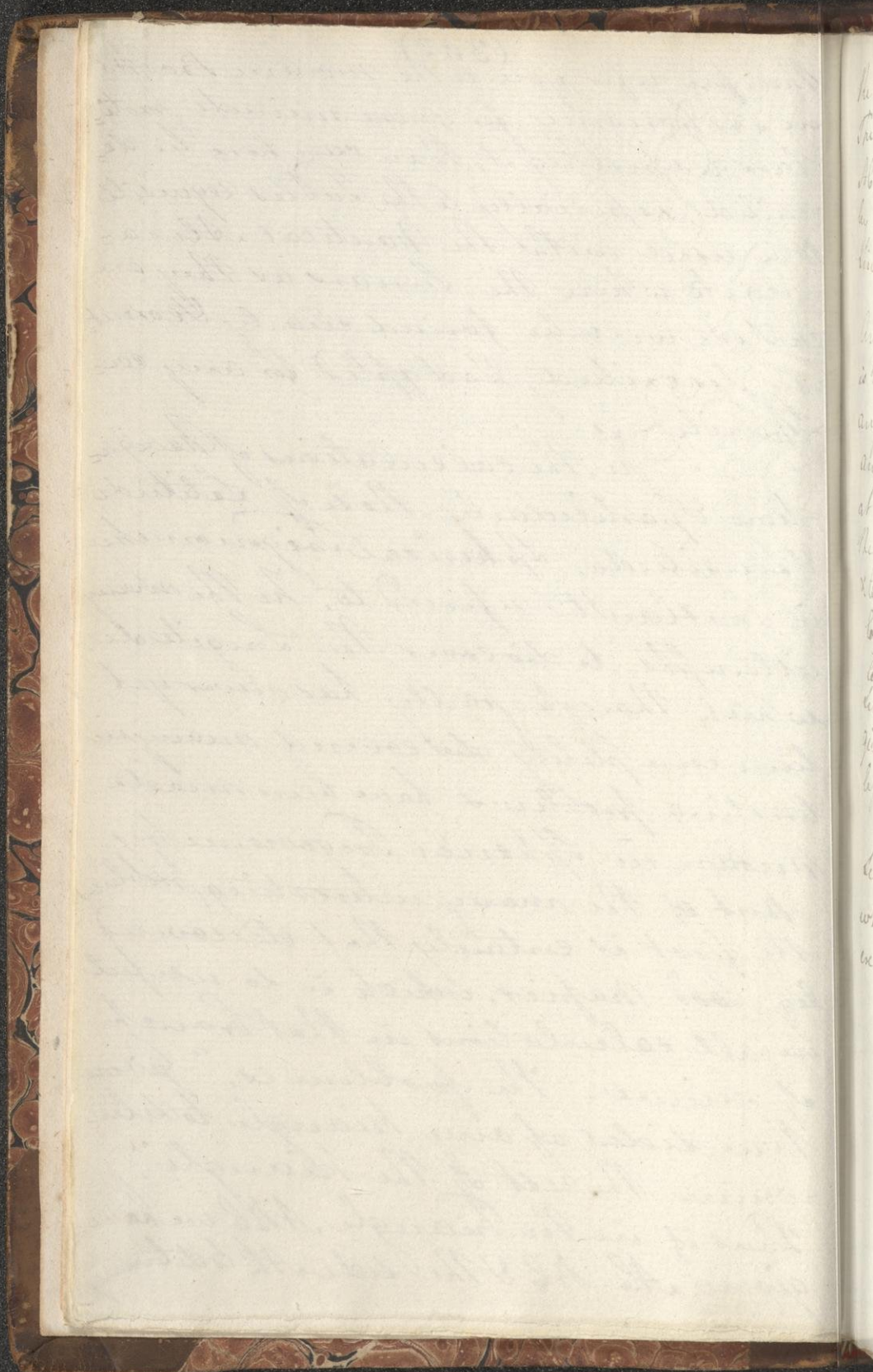


Time Keepers or Chronometers is thus

If your Chronometer be regulated to keep mean time exactly & be set at the mean time on the Meridian of one of the 2 places, whose difference of Longitude is required; for instance be set to mean time at the Meridian of Greenwich Observatory - It is evident that such a Chronometer will continue to show the mean time at that Meridian as long as it continues to go at the same rate, whatever place it may be carried to; consequently if a Watch so regulated be taken on board a ship it will always show the mean time at the first Meridian - Hence if the mean time be found in any other meridian by the preceding problem, the difference between it & the time shown by the Chronometer when the Sun's altitude was observed being turned into degrees and minutes at the rate of 15 to an hour will be the Longitude of the place when the Sun's altitude was observed.

The other method employed is the 2 Lunar Observations. This is a difficult & tedious work, I must





The rest of the Triangle.

The formula is this, suppose

AC, BC, & C to be denoted A, B, C
by b, a, c then we may say the
line $\frac{1}{2}C = \sqrt{\sin. \frac{1}{2}(c+b-a) \times \sin. \frac{1}{2}(c-b+a)}$
 $\sqrt{\sin. a \times \sin. b}$

Another proposition fully as important
is that in which the 2 sides & the included
angle is given. Thus suppose that b & a & the
angle at C be given, then to find the L
at the base we say the Tangent of $\frac{1}{2}$
the difference i.e. $\text{Tang. } \frac{B-A}{2} = \frac{\sin. \frac{1}{2}(b-a)}{\sin. \frac{1}{2}(b+a)}$
 $\times \text{cot. } \frac{1}{2}C$ and likewise $\text{Tang. } \frac{B+A}{2} =$
 $\frac{\cos. \frac{1}{2}(b-a)}{\cos. \frac{1}{2}(b+a)} \times \text{cot. } \frac{1}{2}C$ therefore as $\frac{1}{2}$ the
sum added to half the difference
gives the req. side & the subtraction the
diff. we obtain both angles

A very important instrument at
sea is this before us Hadley's Sextant
which is equalled by none if we
except the Mariners compass.

The Sidereal computation is the most simple, as was explained before, by marking the time any Star comes to the Meridian - This time however is only used by astronomers - That most commonly used is the Solar time, because the time the Sun comes to the Meridian set your clock accordingly, watch it the next day at the same time, it should be in the same place - The Sun however does not always move at the same rate, so that it does not come to the Meridian at exactly the same time so that for 2 reasons this is not quite fit for regulating our clocks, it requires an Equation - This however is remedied by an Imaginary Sun -

The first computation of a year among the Romans was in the reign of Numa Pompilius - it was the Lunar or Greek Year, consisting of 354 days. Numa ordered that at the end of 2 years, 22 days should be added, & at the end of the 4th, 3, this brought pretty nearly right - Some however suppose that Numa did not take the proper Lunar Year of 354 days, but made it, in order to incline it & lucky

We now proceed to apply Astronomy
to the Science of

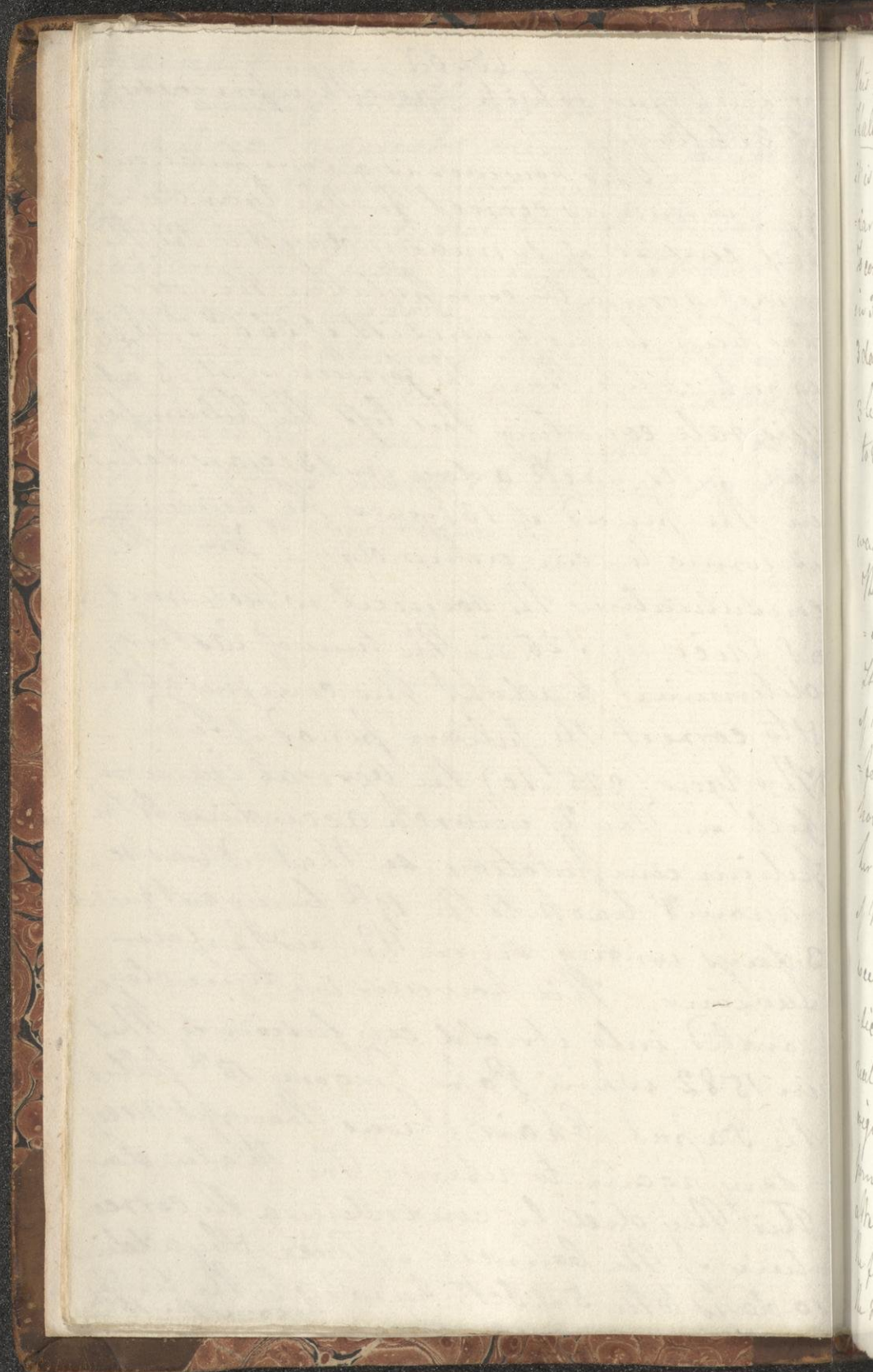
Chronology

This is a measurement of Time
which was frequently considered in
ancient times - It was some time
however before the ancients had reg-
-ular divisions of the year into days
& months &c. The Romans marked
each year particularly by striking
(at its expiration) a nail into the Gate
of the Temple of Janus. A considerable
time previous to this however the Egyptian
-ans reckoned their year of 365 days.
Afterwards they found that this was
not accurate, they then computed it at
365. 6^h, which calculation was not how-
-ever adopted by the neighbouring Na-
-tions - From this the Calendar as it
may be termed fell into great confusion
till in the time of Julius Cesar the
Calendar was reformed & the year was
fixed on as 365. 6^h which has ever since
been termed the Julian Year. Now as
the 6 hours which remained made in
the course of 4 years a complete day
so every 4th year has been called a Bissextile.

occasional or an uneven in 355.
Cicero writing to Atticus from his province
in Cilicia requests him to beg the College
of Priests, to whom was intimated the
additional days, not to make the usual
addition that year, in order that his busi-
ness might be the sooner finished
that he might return to Rome. This was
it is suppose often done by the College
of Priests to answer any particular occa-
sion, & by it produced afterwards the
Years of Confusion -

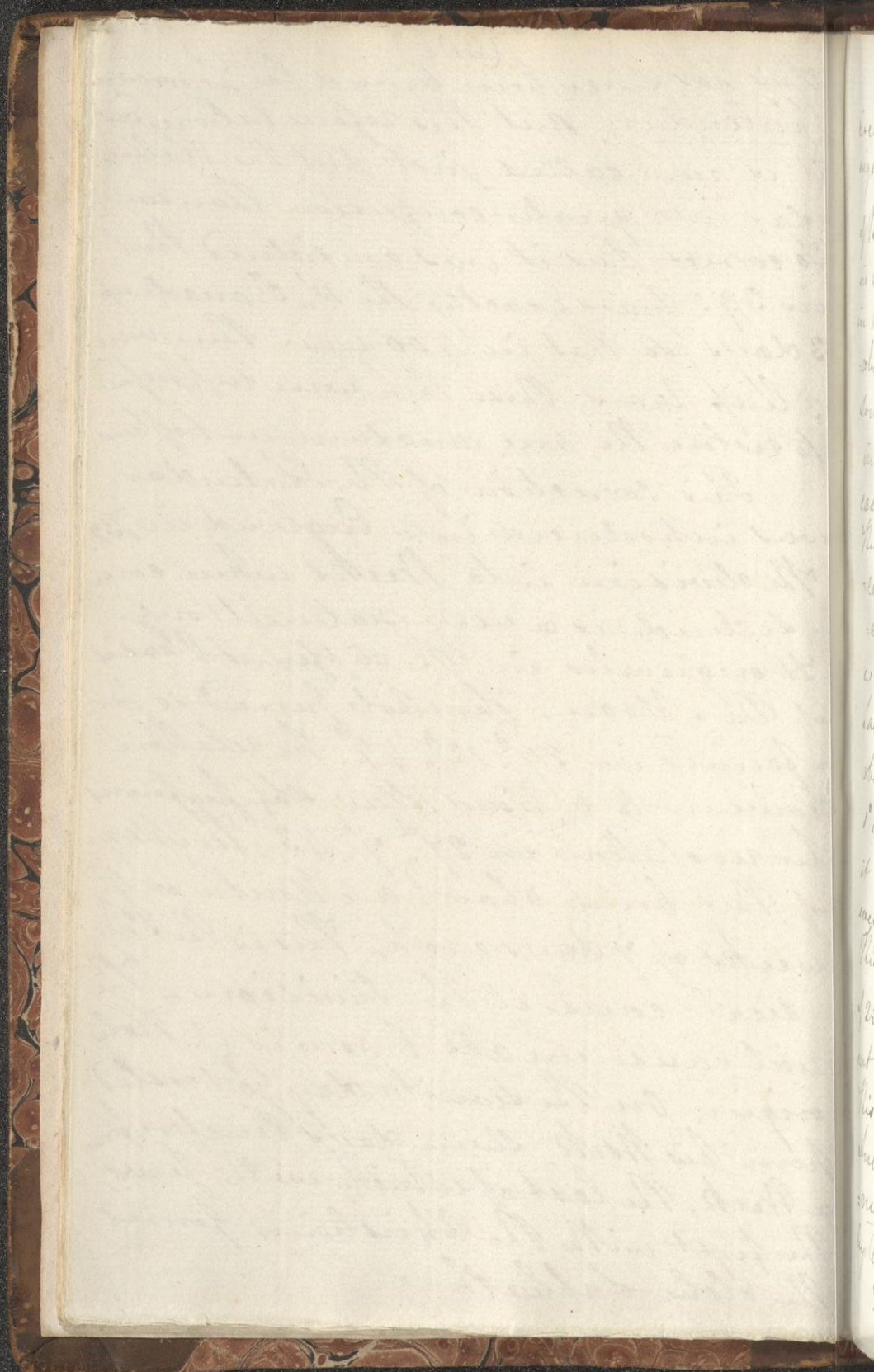
or Leap year which year therefore consists
of 366 days.

This however is a computation
by no means correct for the year does
not consist of so many days. By the
most accurate computation the year
has been found to consist of $365^{\circ} 5' 48''.53''$
which is less than the former by $11''.3''$ at
this rate counting this less the Julian peri-
-od falls back a day in 131 years so that
in the period of 131 years the Julian year
is wrong by an entire day. From the
consideration the Council which met
at Nice in 325 in the time of Easter,
determined to adopt this computation
to correct the Julian period of time -
This year (325 A.C.) the vernal Equinox
fell on the 21 March according to the
Julian computation so that it was re-
-moved back to the 13th being not quite
3 days wrong since the birth of our
Saviour. This however in time degen-
-erated into its old confusion so that
in 1582 when Pope Gregory 13th filled
the Papal Chair it was thought need-
-sary again to reform the Calendar.
This they did by considering the correc-
-tion of the Council of Nice by adding
10 days to the 5 of Oct. by which the time
became the 15th



This has since been termed the Jegorian
Calendar. But this reformation as
 it is now called just put the Calen-
-dar into greater confusion than ever
 To correct this it was considered that
 in 391 years exactly the 11^h 3^h made up
 3 days, so that in 400 years there were
 3 leap years, these then were supposed
 to restore the true measurement of time.

This correction of the Calendar
 was introduced into England in 1582.
 The division into Weeks when con-
 sidered is a very natural one.
 It originates in the different Phases
 of the Moon. The whole period is per-
 formed in 29^d 12^h 44^m. In relation
 however to a fixed star she performs
 her revolution in 27^d 7^h 43^m. The Moon
 of this being about a Month or 4
 weeks of 7 days each. This is the Phy-
 sical cause of the Division. The
 real cause we all know is of Holy
 origin. On the seventh day God rested
 from his work, seven days therefore form
 a Week, the last of which with Jews,
 the first with the Christians forms
 the Holy Sabbath.



(307)

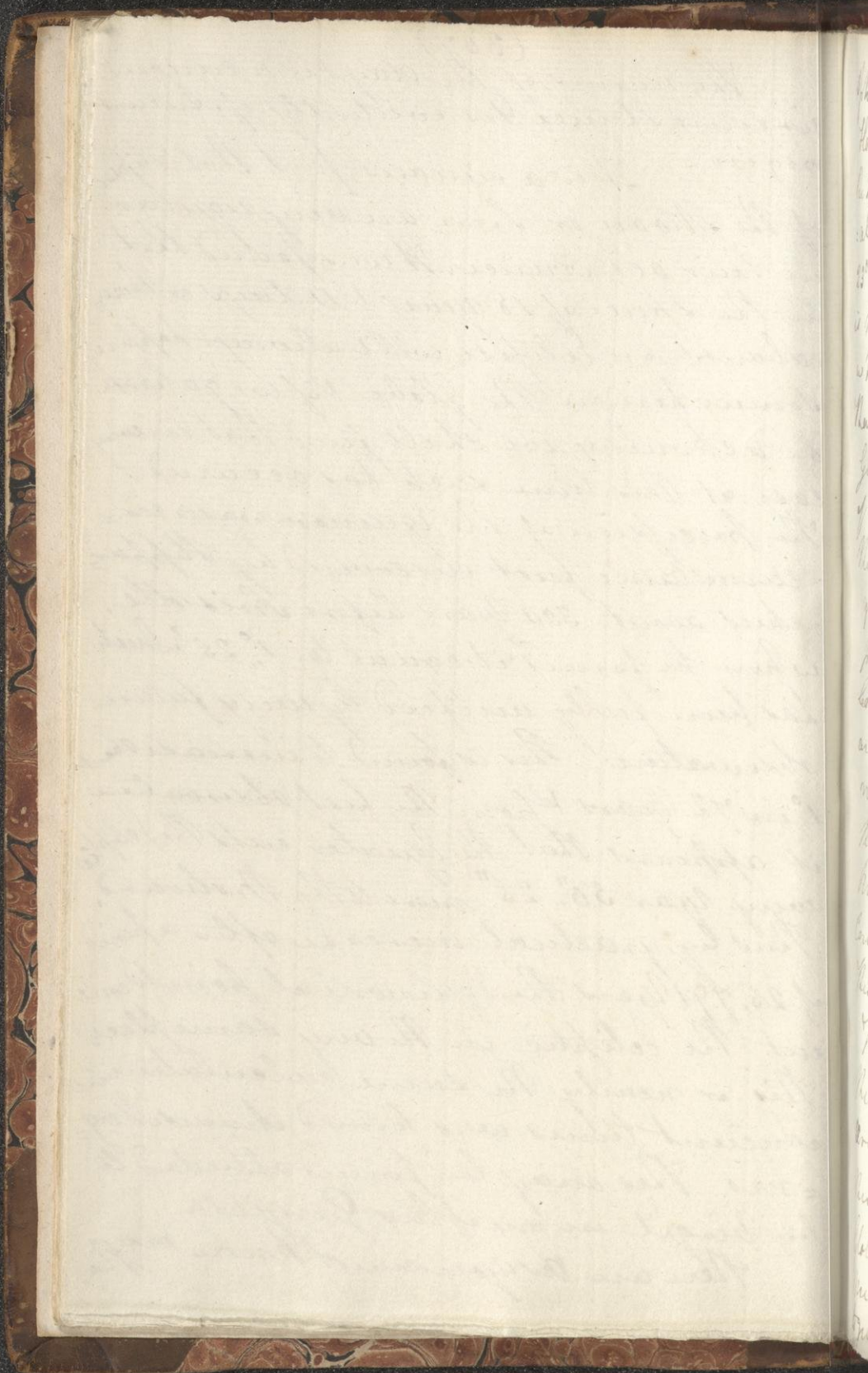
The names of the days is a curious circumstance & is evidently of Ancient origin.

It is a curious fact that Eclipses of the Moon or Sun are very regular in their occurrence. It was found that in the space of 18 years & 11 days or thereabouts an eclipse will always happen somewhere on the Globe. If we go back in reckoning, we shall find that in every case at this time such has occurred.

The Precession of the Equinox was a circumstance first discovered by Hipparchus about 300 years before Aristotle, when he found it equal to $1^{\circ} 25'$. Such has been fully verified by every future observation. This is found to increase about 1° in 72 years & from the best observations it appears that the Equator cuts the Ecliptic every year $56'' 25'''$ more to the Northward.

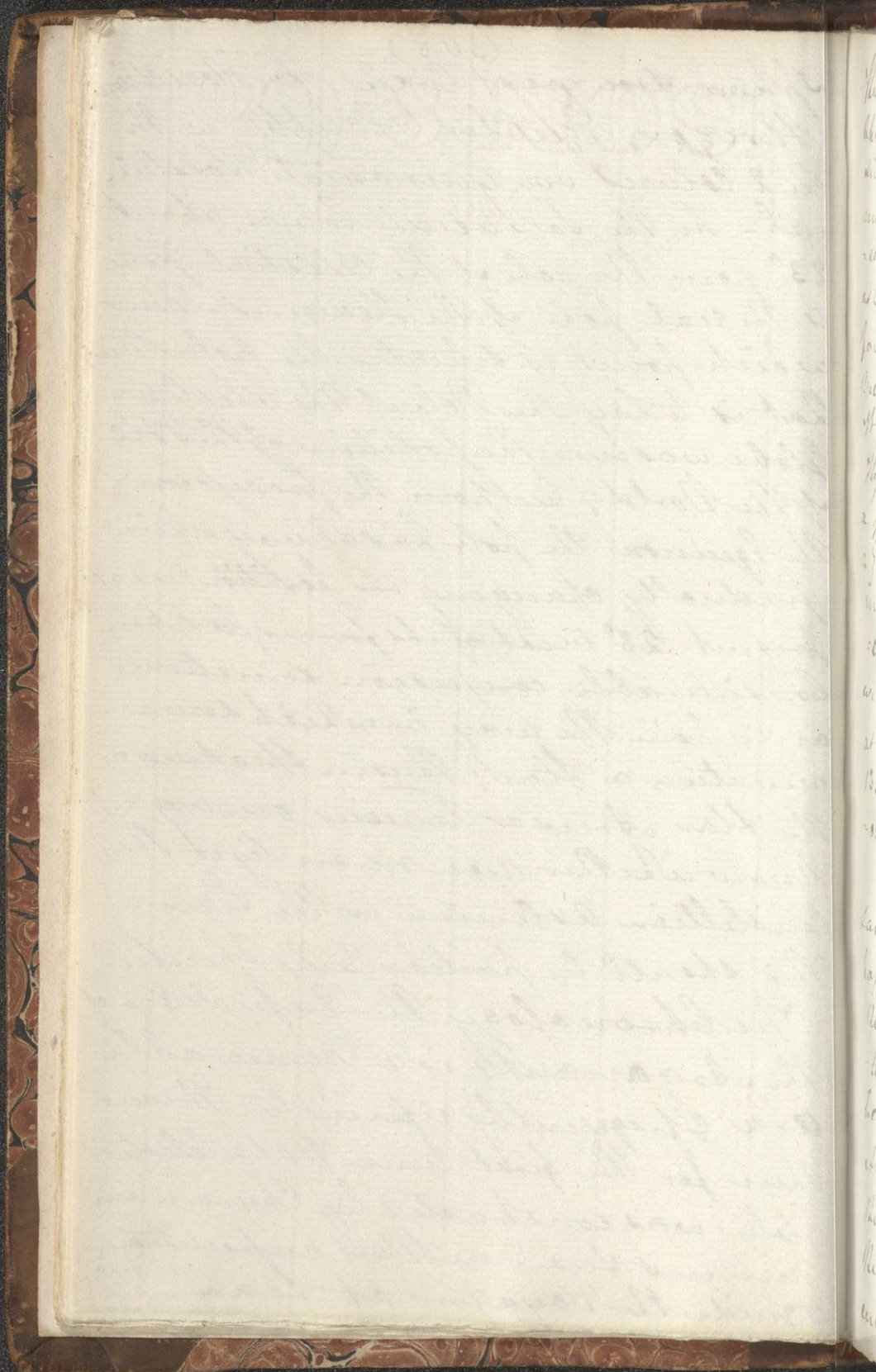
Thus by gradual increase after a period of 25,791 years the Equinoctial points will cut the Ecliptic in the very same place. This or nearly the same calculation in ancient times was termed Annus Meg-
-nus. This may be found alluded to by Virgil in one of his Georgics.

Here are as you must know on the



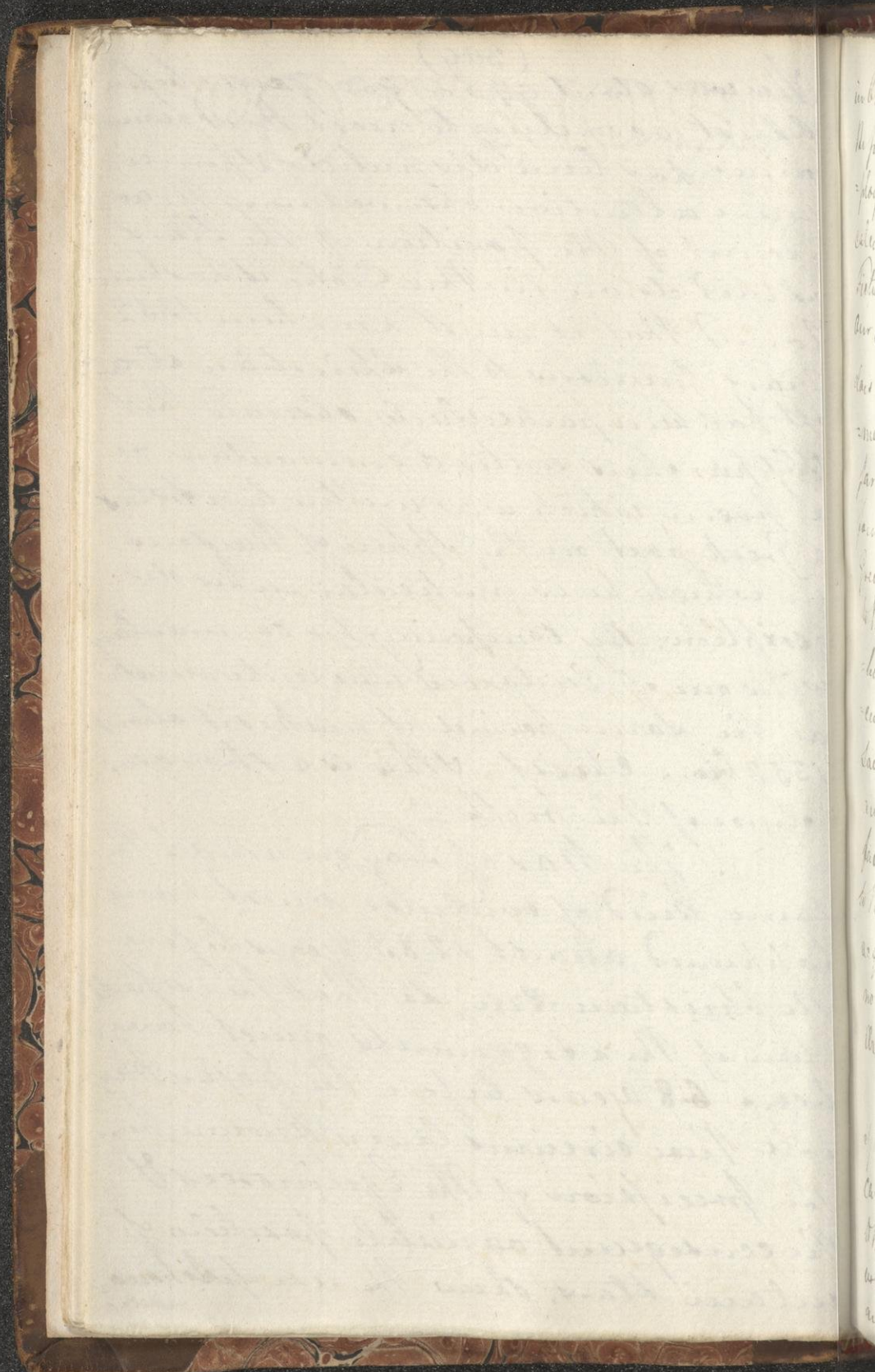
Sphere draw great Circles, the Meridian, Horizon, Equator, & Ecliptic with the 2 Columns viz. Equinoctial & Solstitial. In the Solstitial Column about 23° from the pole of the Celestial Globe is the real pole of the Heavens - Near which point is situated the polar star. That is to say the Pole of the Celestial Globe was once the position of the Pole of the World; but from the precession of the Equinox the pole has always been gradually changing its position & is at present 23° west of its former position. Considerable confusion sometimes arise from the way in which some mention a Star; Thus in speaking of the Star Arcturus or Taurus, one may not know whether you mean by it the Constellation Asterium or the Sign. This should be particularly specified.

The Chronology the Expeditions of the Argonauts is a numerable Aera frequently referred to. It was then for the first time that a Celestial Globe was constructed by Cheiron and Musaeus used on that expedition to guide the Voyagers at Sea.



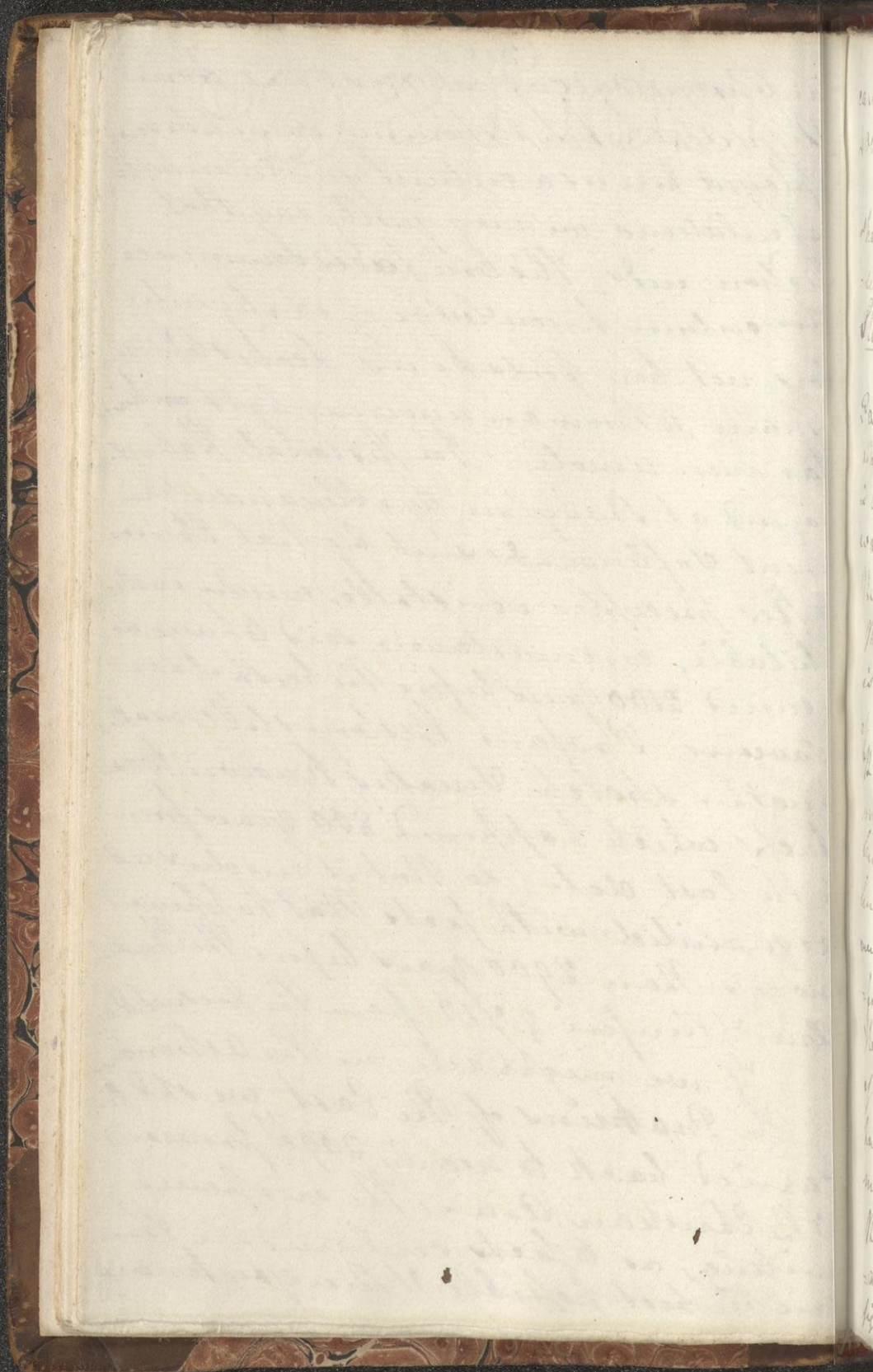
This was about 940 or 950 years before Christ, according to most this however since has been disputed, & hence more attentive observations of the account of the position of the Stars as laid down in this Globe it has been found that it must have been 1352 years previous to the Christian Era. It has been particularly observed that Hipparchus writes a commentary on a poem which was written by Aratus a Greek poet on the Sphere of Muses in which he is particular in his description. By comparing his commentary with one of Eudoxus who wrote much at the same period it makes it about 1353 before Christ. This is a strong evidence of the truth.

The War of Troy on much the same kind of evidence must have happened about 1283 years before the Christian Era, so that the Expedition of the Argonauts must have been 68 years before the Trojan War. All these circumstances known from the precision of the Egyptians & the consequent variable position of certain Stars, show the use of Astro-



in Chronological calculations. From
 the period when Astronomy came to be em-
 -ployed here as a certain guide in such
 calculations, we may justly say that
 Fiction ends, & the true facts commence.
 Our certain knowledge of antiquity
 does not here forsake us. Facts still re-
 -main to throw an unerring light on times
 far more remote - The Historical Nabuchodon-
 -sor found at Babylon by Alexander the
 Great & afterwards sent by that Prince
 to his preceptor Aristotle under indis-
 -putable, circumstances, said to have oc-
 -curred 2100 years before the birth of our
 Saviour. Profane History still makes
 another sheet of unaltered known & cer-
 tain facts which happened 800 years prior
 to the last date; so that it renders us
 acquainted with facts that happened
 no less than 2900 years before the Christian
 Era & therefore 4912 from the present day.

If we might rely on the Astronomy
 of the Nations of the East we should
 carry back to nearly 3090 years
 to the Christian Era. The inspired
 writings, as to facts contained in them
 are the best possible & these you know



carry us as far back as the Creation
4004 B.C.

Now proceed to conclude this
short account of astronomy by con-
sidering the distances of the Fixed
Stars from the Earth.

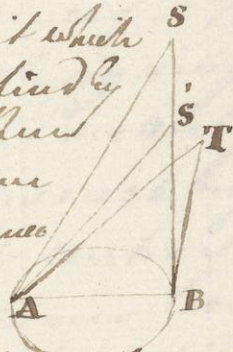
Of these some have much greater
Parallaxes than others. The star on
which most observations have been made
is one called the γ Draconis. Dr. Bradley
was the first who accurately observed
the Parallax of this star. He found
that it did not exceed 1". The γ Draconis
is a star which forms either a point
of the first or a bright star of the second.
I might be said why did not Dr. Bradley
make his observations on the Dog star
being so much more conspicuous -
but the γ Draconis, passed almost
over the Zenith of London which there-
fore made him prefer observing it.
He found that the γ Draconis consisted
of 2 stars together, which observation
has been confirmed by Herschel. We
may therefore lay down as a rule
that the fixed stars of the second or
third do not exceed 1". In the following
figure where I represent a fixed star

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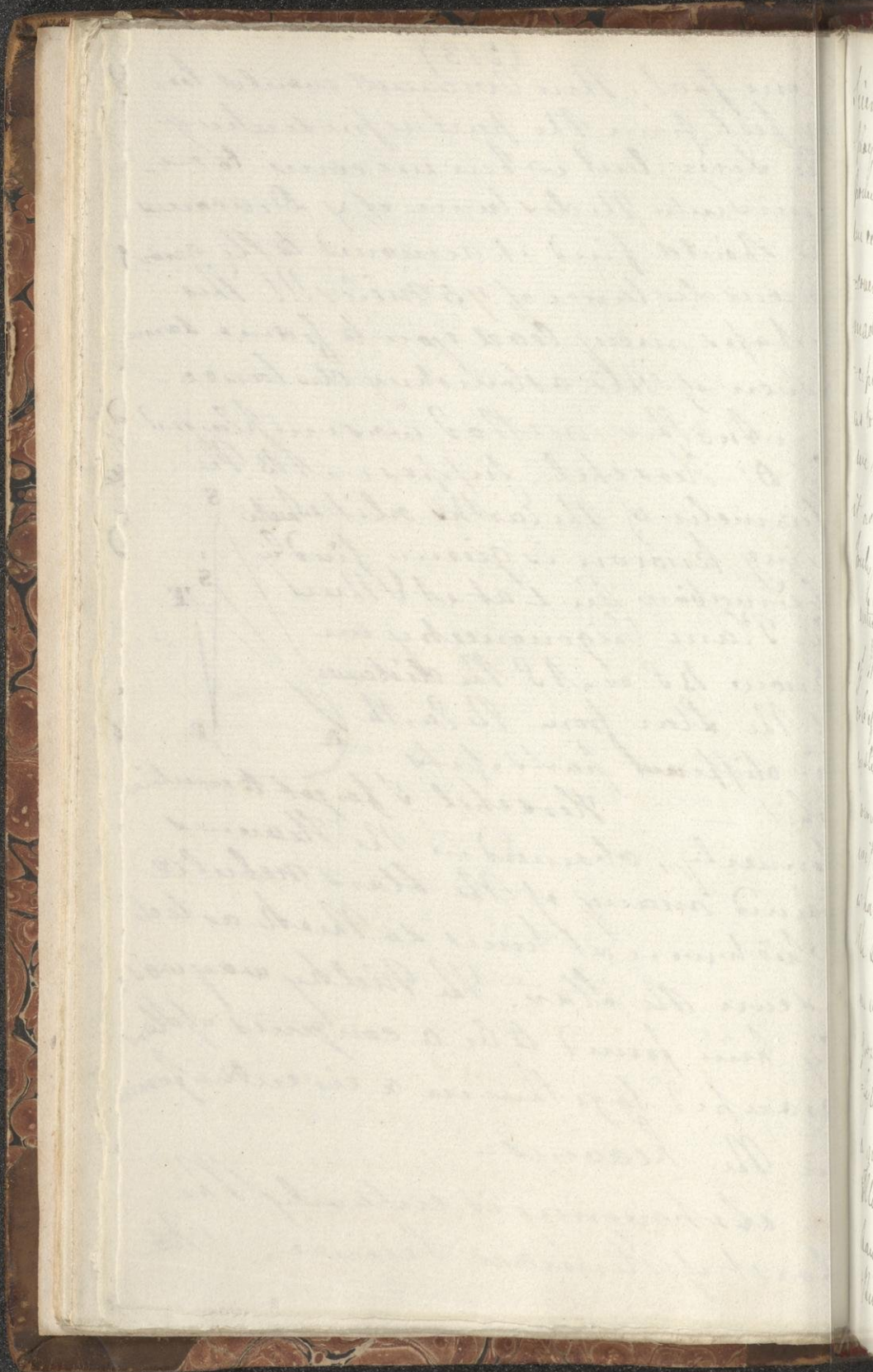
of one foot. Now Uranus would be 19 feet from the part representing the Sun, but when we come to enquire into the distance of γ Draconis we should find it amounted to the enormous distance of 75 miles!!! This perhaps may lead you to form some notion of this astonishing distance.

Another method was employed by Dr Herschel. Suppose AB the diameter of the Earth's orbit which being known is given find by observation the Lat^d at A then by Plane Trigonometry we know BS or AS the distance of the Star from the Earth in different parts of its orbit —

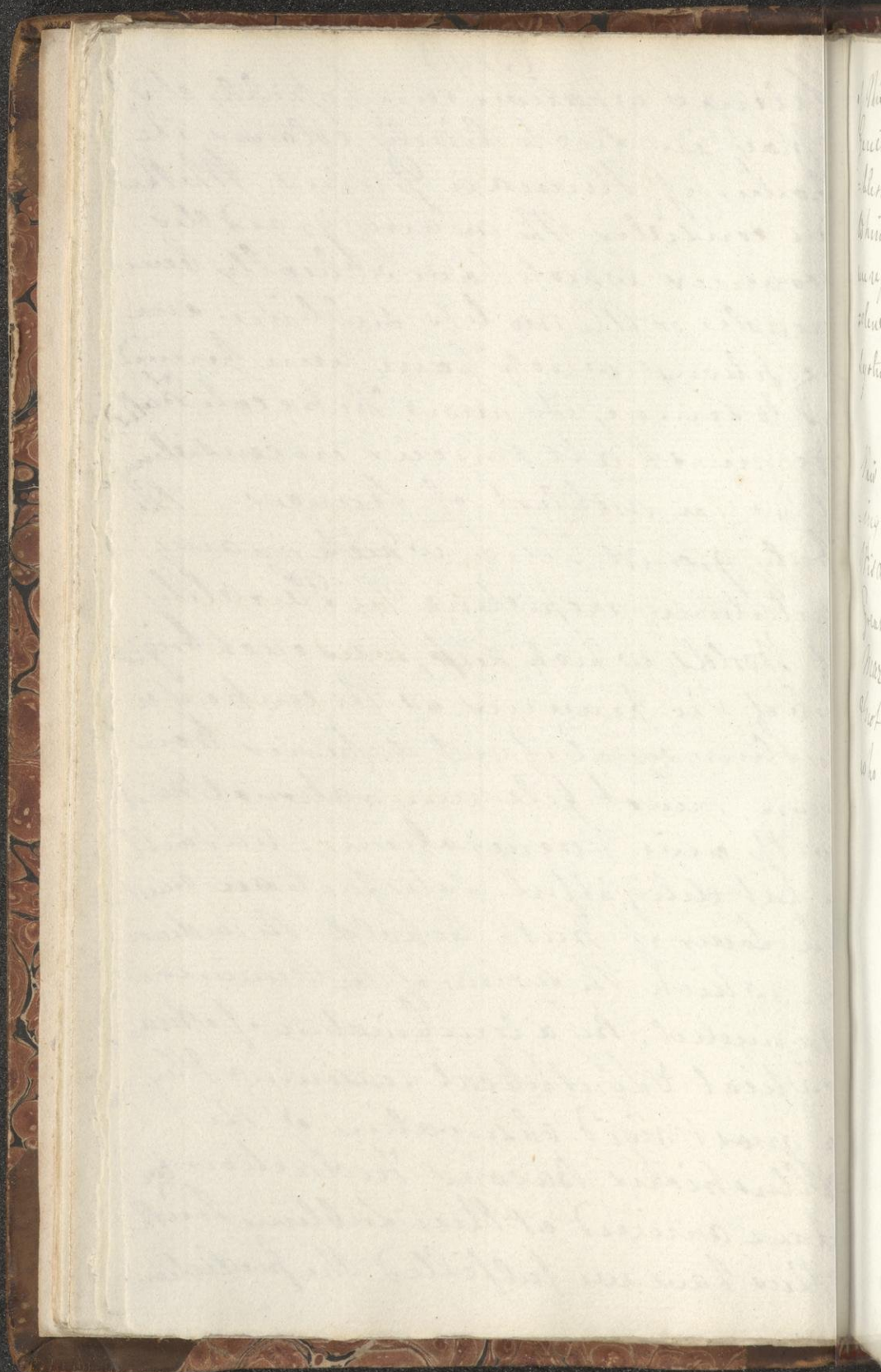


Herschel I forget to mention formerly, observed in the heavens round many of the stars nebulae which were at times so thick as to obscure the star. The Milky way was by him found to be a congeries of stars grouped together in a circular form in the heavens —

Astronomy is certainly the boast of Human Science. No



Science whatever can possibly do -
 may in such lively colours re-
 produce of Human Genius. Whether
 the celestial The many grand dis-
 coveries which have actually been
 made or the no less sublime con-
 ceptions which have been formed
 as to some of its more intricate parts
 we must all concur in considering
 it as the noblest of Sciences - The
 truly grand Theory, which many
 entertain, respecting the Plurality
 of Worlds, which supposes each bright
 orb of the heavens as the centre of a
 system equal if not superior to our
 own, must fill every rational Mind
 with true Veneration - And with
 what delightful Satisfaction must
 the Lover of Truth behold the Evidence
 on which the system of the Universe is
 grounded. By a combination of Ana-
 lytical & Synthetical reasoning & by
 a most rigid observation of the
 illustrious Bacons Induction we
 have arrived at these sublime Truths.
 Thus have we fulfilled the predictions



(315)
of this Great Philosopher. This fertile
Genius paved the way for the No-
-blest & convenient in Science; and
whom shall we always look when
we reflect on the Mathematica Sci-
-ence which supports the Grand
System of Nature -

Who for a moment can consider
this wonderful System without Ador-
-ing the Goodness & Condemnate
Wisdom of that Being who is its
Great Author. Who can behold the
Mazes of Astronomical Science
not exclaim, "Surely there is a God
who ruleth over all"

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Having finished Astronomy
 The next part of the course to which
 we proceed is

Optics

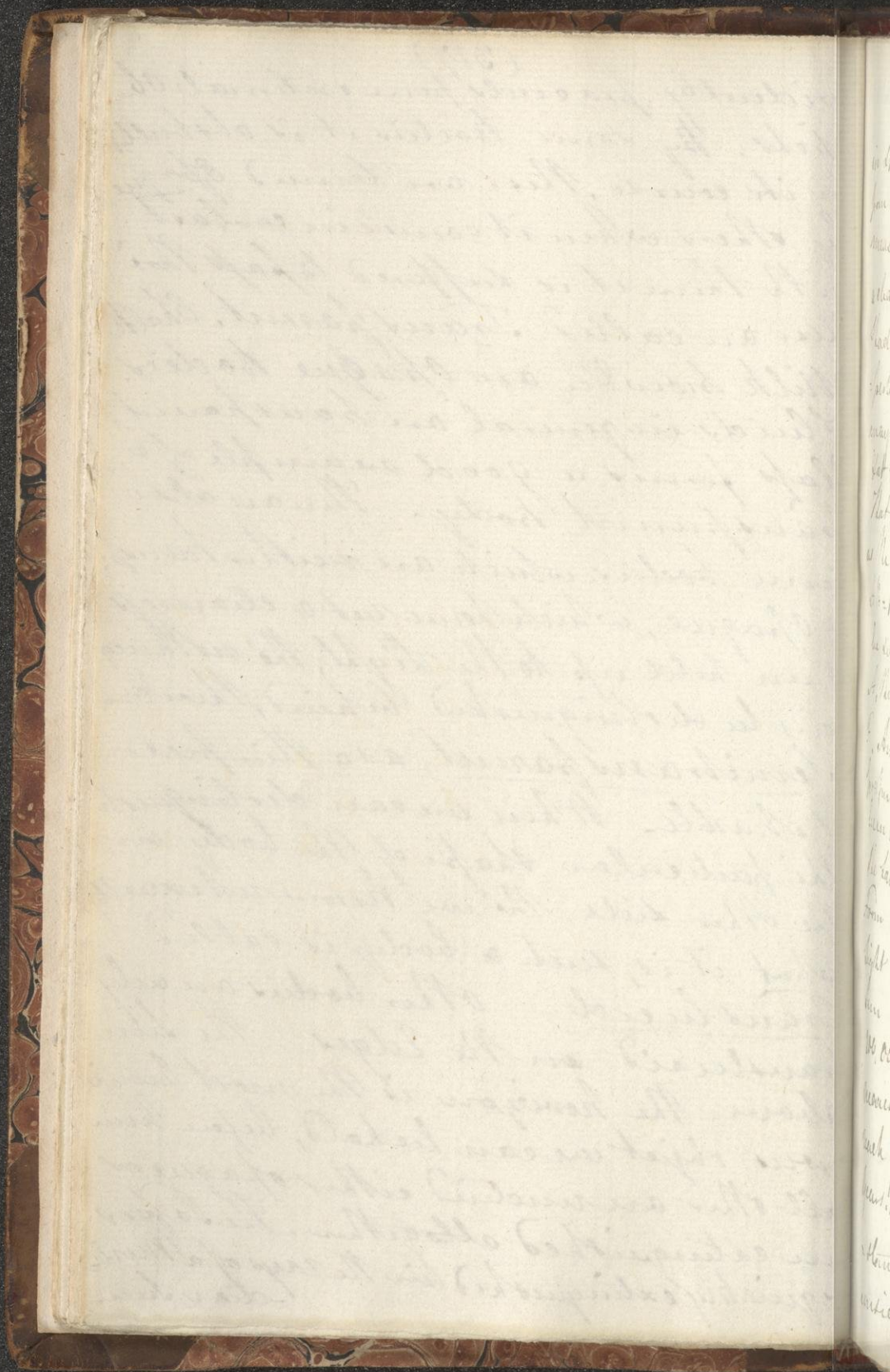
This certainly is the Science in
 passing from Astronomy to which
 we make the least transition. It
 approaches nearest to Astronomy
 of any other Science in the grandeur
 of its discoveries & the intricate inge-
 nuity it displays. For these accounts
 therefore it merits our most consideration.

Optics is that Science which
 treats of the Nature of Vision & the
 Properties of Light. What vision is
 it is unnecessary to explain. Light
 proceeds not from the Eye, but from
 external things it is communicated
 to the Eye; it evidently does not pro-
 ceed from the Eye, otherwise why
 do we not see as distinctly when
 the Sun has sunk beneath, as when
 he is above the Horizon. Light there

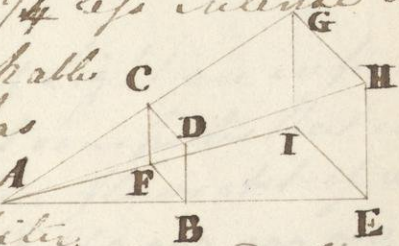
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evidently proceeds from external ob-
 =jects. By some Bodies it is obstructed
 in its course, these are termed Opaque
 by others when it comes in contact
 with them it is supposed to pass thru
 them are called Transparent. Chalk
 Milk Snow &c are Opaque Bodies.
 Fluids in general are transparent.
 Glass forms a good example of a
Transparent body. There are also
 some bodies which are neither transp.
 or opaque, which have yet a clearness
 when held up to the Light, tho' nothing
 can be distinguished behind, these are
Semitransparent, as a thin piece
 of Marble. When we can distinguish
 the particular shape of the body on
 the other side, tho' we know not exactly
 what it is, such a body is called
Translucent - other bodies are only
translucent on the Edges. The Sun
 above the horizon is the most lumi-
 nous object we can behold, before him
 all other are united either opaque or
 are extinguished altogether. The Paper
 is quickly extinguished in the rays of a Meri-
 dian Sun.



Vision is always performed in straight lines which is obvious from various circumstances. Thus the measuring of heights by shadows is a clear proof of the direct lines of the shadow or vision. Of the various properties of the light the following may be considered as an elementary one. That the same time a satisfactory one. That it diminishes in intensity inversely as the square of the distance. Thus if $AB = 132$. If then the intensity of light be supposed $\frac{1}{2}$ at B of what it is at A, then will it be $\frac{1}{4}$ less intense at F. Another remarkable property of light has been obtained from the satellites of Jupiter. From this it has been found that light takes $8^s.13''$ to reach us from the Sun which is a velocity nearly = 200,000 miles in a second! From the nearest fixed star it takes a year to reach us & from *Dracouis* nearly 7 years!! From this various other distances light has in general been considered as a material substance.



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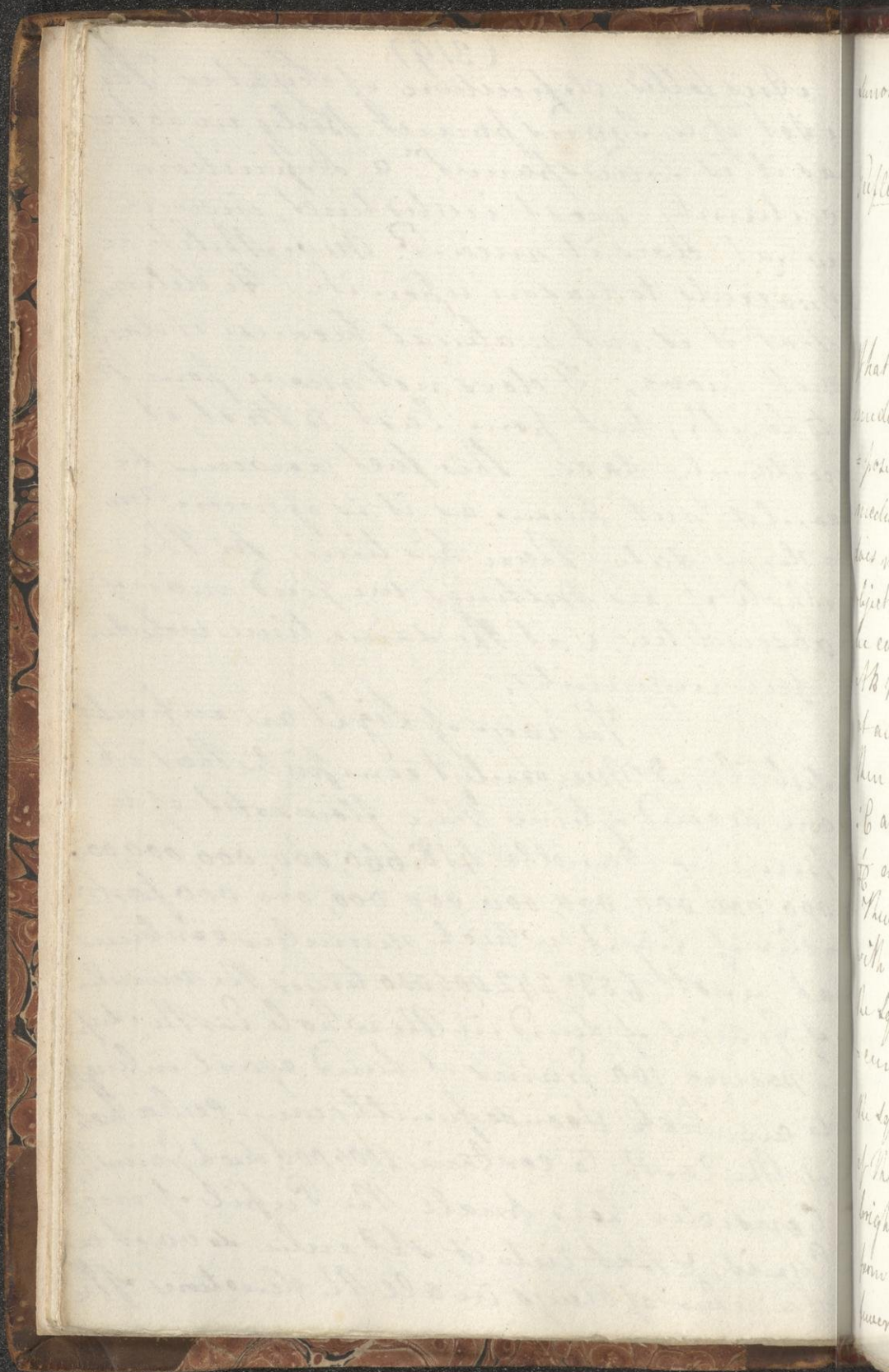
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A

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Aristotle's definition of Light is "The
 exit of a Transparent Body in so far
 as it is Transparent" a Definition
 certainly most indistinct, indeed
 what does it mean? Nevertheless he
 proceeds to reason upon it. He determines
 that it is not material because it does
 not move. It does not move from N
 to South, but from East to West it
 certainly does. This fact however he
 could not know, as it is of more mo-
 -dern date, than his time. In the
 whole of his writings we find many
 absurdities, & at the same time wonder-
 -ful ingenuity.

The rays of Light are infinitely
 subtile. Dr. Huesentys computes that in
 one second of time there flows out of a
 burning Candle 418.666,000,000,000,000
 000,000,000,000,000,000,000,000 parti-
 -cles of light which number contains
 at least 6,337,242,000,000 times the number
 of grains of Sand in the whole Earth; sup-
 -posing 100 grains of Sand equal in length
 to an inch & consequently every cubic inch
 of the Earth to contain 100,000 such grains!!!
 Consider how small the Pupil of ones
 Eye is, & that into it sh^d enter so vast a
 number of Rays in all the directions of the

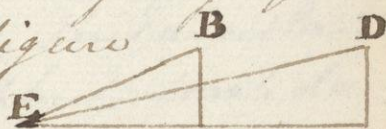


Surrounding Landscape

Vision is of 3 kinds. Direct
Reflected & Refracted *ist*

I Direct Vision

Light varies much in density. What Light passes thro' is called a medium, viz direct vision it is sup-
posed always to continue in the same medium. The density of Light however does not constitute the brightness of an object. If E in this figure



is called the eye, AB the diameter of a circumference at any distance, BE & ED the same. Then $AB : A$ (size of the object at A) : $CD : C$ also $\text{Tang. } AEB : \text{Tang. } CED :: \frac{1}{AB} : \frac{1}{AC}$ or simply $AEB : CED :: AE : AC$.

Thus the angular space varies with the distance it is inversely as the square of the distance. For their circumferences are to one another as the squares of the diameters. Many of the celestial bodies are of equal brightness with the Sun himself, but from their enormous distance transmit fewer rays & are therefore quite eclipsed.

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by his Splendour. This holds also in the case of reflected light sometimes but not when the Atmosphere is thick & hazy. From this we inquire how far may we remove an object before the Eye loses sight of it? a tolerably good Eye will lose it when it subtends an angle about 1° some even $30'$. We may determine by measuring the distance at which they can see a candle on one day & comparing it with any other day. Thus ascertain the comparative brightness of each day. Let us take Imagines into consideration. One may ask how comes it that when the Sun rises the Stars vanish? A candle in the Rays of the Sun is extinguished this arises from the superior brightness of the one illuminating the Vanishing the whole day, when the Sun shines brightly, appears as light & luminous as the candle or even the Stars hence they are not distinguishable. If we exclude the lateral rays in the day time we might see the Stars distinctly hence the Stars may be seen from the bottom of a deep well & appear over the zenith.

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A good Telescope also shows the Stars in the Day time. They do not sparkle but are then in a state much better adapted for Astronomical researches. The Telescope also magnifies the angle which the object subtends.

On the tops of any high Mountains the Stars may sometimes be seen in the Day time - Lacessure on the top of Mount Blanc saw them distinctly. This Mountain as you know is 15,000 feet above the level of the Sea. On the top of these Mountains it is observed that the Sky appears so much darker blue than it does below.

The different Intensities of light of the different Planets in regard to their situation as to the Sun are as follows Mercury, 7. Venus, 2. Earth, 1. Mars, $\frac{1}{4}$. Jupiter, $\frac{1}{29}$. Saturn, $\frac{1}{90}$. Uranus $\frac{1}{360}$ being all inversely as the squares of the distances.

There is not any uncertainty of sight when the Sun shines from a pure unclouded sky, when the sky is covered with white clouds, by reflection it is the lightest. It may also be observed that when in the Day time the

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figure of the Moon during Sunshine is approached by a white cloud, it is hardly to be distinguished. Were we then to suppose the whole sphere around us to be covered by the Moon, which is common subtends an angle of $15^{\circ}.45''$, if then we wished to find the Moons disk in such a state, the formulae is $3.1416 \times \text{Line } 15^{\circ}.45''^2$ or $(\text{Lin. } 15^{\circ}.45'')^2 \times 3.1416$ This is the area of the Lunar disk

Of this a very good account may be found in Lamy the Optic's. Photometre or the measurement of light is better discussed by the French Mathematician. Leslie has added much to this subject by his Differential Thermometre which is so easily converted into an excellent Photometre.

There is the greatest difference in the degree of light in the open air, & that in an inclosed room, where to those within there appears so much light. That such is the case is evident from the circumstance that if you look into a Room thro' an open Window from some distance all within seems dark. — The consideration of direct vision & light running in straight

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lines, with the various different ap-
-pearances which are caused thereby.
brings me next shortly to consider

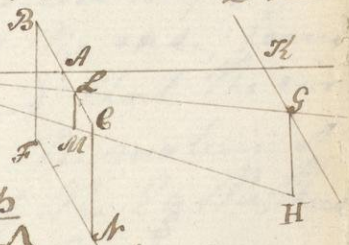
Perspective

I shall merely take notice of the
general principles. By perspective
is meant the picture of any object.

In this figure KGH being the
object to be represented, then if AE
 $= D$, $AE = \Delta$, $KE = h$, & $GH = p$, then
we want AL which we shall
call x , & $LM = y$. Then (by Parallel
lines) $KE : EA :: GH : AL$ or which
is the same as $D + \Delta : \Delta :: h : x = \frac{\Delta h}{D + \Delta}$.

Now to find y
we say as $KE :$
 $EA :: GH : LM$ or to
be otherwise expressed
as $D + \Delta : \Delta :: p : y = \frac{\Delta p}{D + \Delta}$

This is the whole Theory which anyone
may see is extremely simple. There
is however there are many Corollaries
& particular rules which shall be
hereafter explained, but what you
have now before you is the Theory
of Perspective - This is a rule that
all parallel lines when represented
in perspective converge to a point -



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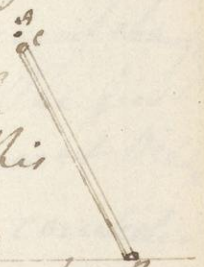
In the Year 1672 a French Astronomer observed that the Polar Star had changed its position in the Heavens by $20''$ which circumstance confirmed by many observations puzzled Mathematicians extremely to ascertain the cause.

Dr Halley in London observed a change in γ Draconis the Star on which in 1725 as I before mentioned he discovered the Parallax. He in time found out the cause of this irregularity. This merely occurred by accident to its discoverer, so that it never was predicted by any one that such a thing would happen; but he soon seeing it the case, found out the cause, he found that the circumstance lay not in the motion of the Star, but in that of the Earth; thus looking towards S, from the motion of the Earth constantly in its orbit, the object cannot be seen from A as in a straight line. Suppose the Earth is moving from A to B. Take C, a point so that $AE :: AB :: 10313 :: 1$. Then thus taking D into account the motion of the Earth make FE on the opposite side equal

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to E & the true direction of the Telescope for seeing S perpendicular to A . For the ray entering the Telescope is from the Earths continual motion bent in its course at E . And the angle $FEA = 20''$ This then accounts completely for his having seen the Star removed $20''$ from its 1st position.

If the Earth moved in a different direction the angle FEA would be much the same, it would if any thing be somewhat less as in this figure before you.  Such then was the case with the Star of Draconis which Dr Halley observed. The Star had never changed its position, but we were deceived by the Earth.

A very simple experiment if well managed might fully illustrate this. Suppose drops of rain falling, I would in that state you wish to make some of them pass thro' a tube, without touching this would be done, Suppose 

At a drop of something falling perpendicularly & that BC is the tube moving along BD from B to D ; then after calculating the rate of falling at A

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we incline the tube accordingly. This may lead you to form an Idea of the case above, but to perform this experiment accurately is extremely difficult.

Many of these difficulties which perplex Philosophers at first are often very dissipated, & the cause to be inquired very simple. The motion of two makes some suppose that particular Stars move & then change their places. The cause above or the fact itself was never suspected by any one; no one predicted them before hand, but Dr Halley was the first to discover it in his observations, on the γ Draconis. Vast & considerable labour came at length to the conclusion that the Star really had not changed its position, but that the Earth's motion in its orbit was the cause of the apparent change.

Here we conclude the first division of Optics viz Direct Vision. We next proceed to consider it as reflected viz Catoptrics.

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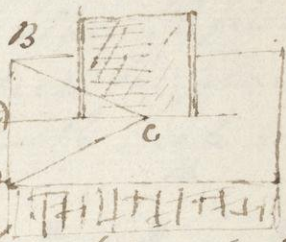
II Catoptrics

Or The Reflection of Light. All luminous bodies have the power of reflecting light, or after having received light on their surface they have the power of again throwing it off. They also reflect Images quite distinctly if they are very luminous. All Glass Mirrors are remarkable for their power of Reflection.

The great property of Reflection is that the Reflected Ray is always thrown off at an equal angle with which the Incident falls on the Glass in other words "The Angle of Reflection is equal to the angle of Incidence;" We may represent this by a figure suppose AB is a Mirror, let D be some object whose image falls on the Glass at C it is then reflected F to E at equal angles that is draw the perpendicular $C.F$ then the reflected angle $ACD = BCE$, but we more commonly express it thus $DCF = ECF$.

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This may be proved by a very simple experiment. Thus if we lay down on a plane board an angle ACB & bisecting it in CD & placing a mirror along the line CD shall see on looking into the Mirror this satisfactorily proved.



If then we have the incident ray, it be required to determine in what direction it will be reflected this is the construction. If EC be the incident ray let fall EB perpendicular, extend it

till $BC = BE$ then join EC & produce it to D , then CD is the direction of the reflected ray.



For the triangles ECB & BCD may easily be proved equal, therefore the angle $ECB = ECD$ but $ECB = DCB$ therefore $DCB = ECD$ that is the reflected angle = the incident.

Another important property to be proved is that "if an object be reflected by 2 Mirrors whose planes"

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"are at right angles to the same plane"
 "Then the angle made by the first
 incident ray with the other Reflected
 is double the angle which the planes
 of the Mirrors make with each other;

Thus if HB & GD

be two Mirrors if E L H A B
 be the incident on
 GD at C & from that be
 reflected to A & then again
 in the direction A F N
 then its first EC & its last F C
 AF be produced to meet in
 F then $\angle EFA$ is double of the $\angle$
 ALB made by the planes of the Mir-
 =rors. For first $BAC = ALB + ABL$ if
 FA be produced then $MAB = 2BAC$
 therefore $MAB = 2ALB + 2ABL$ or $=$
 $ABF + 2ALB$ but $MAB = ABF +$
 AFB consequently $AFB = 2ALB$
 2. E. D.

This simple property is the
 foundation of that valuable Instru-
 =ment before mentioned Tadley's
Sexant -

As yet we have considered
 Rays of light as reflected only
 from plane surfaces. Let us now
 take into consideration the reflecting

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from Concave Mirrors

Suppose then that B & D is a concave Speculum whose centre is C and that the rays proceed from O in the direction $O A$. The focus is then thus found. Suppose O

B any point in the Speculum draw $O B$, $B C$ if then we draw $B F$ making the $\angle C B F = O B C$ then the focus of the Speculum is F lying between the centre C & A the vertex of the Speculum. Now in the Triangle $O B F$ since $B C$ bisects the angle at the vertex then $O B : B F :: O C : C F$ but if instead of $O B$ we take $O A$ for there is little difference, if for $E B$ we take $A F$ we have then $O A : A F :: O C : C F$.

To gain a general expression suppose $O C = d$, $C F = x$, $C A = r$ the ratio viz as $A O : A F :: O C : C F$, then becomes as $d + r : r - x :: d : x$. The extremes being equal to the means we have $(d + r)x = (r - x)d$ that is $dx + rx = dx - dx = d(2d + r)x = d^2$ therefore $x = \frac{dr}{2d + r}$ This then is the property of Catoptrics with regard to curved surfaces - This result

$x = \frac{dr}{dt + r}$

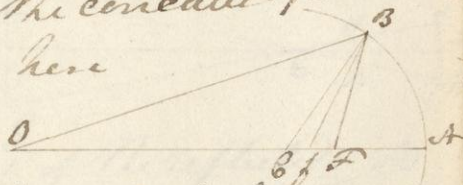
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This Reflection then resembles in some degree that of a plane surface for after the Ray falls on the Speculum it is thrown off in the direction of the focus at an equal angle. The focus F is where all the rays from a luminous object at O wd be concentrated. In this point were the rays of the Sun collected the heat produced wd be of the most intense nature. For this reason it is termed the focus;

In this figure the same as the last representing the concave Speculum illuminated by O here

$$OF \times Ff = \frac{r^2}{4} = CF^2$$

This is a general property one which invariably remains the same. The point O for the focus is very variable. When O is at any common distance beyond C the expression for CF making the point F was $\frac{dr}{2d+r}$ When O is infinitely removed then $CF = \frac{1}{2}r$ When O comes so near as C then it is $\frac{dr}{2d+r}$ When O comes any where nearer the vertex A



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 viz therefore $\frac{-dr}{-2d+r}$

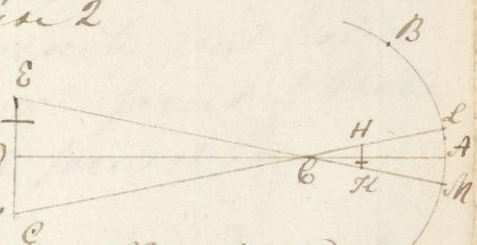
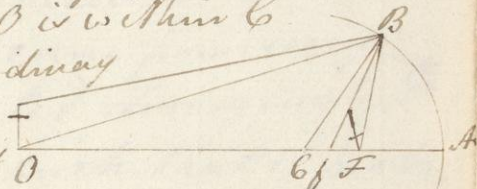
Suppose that instead of a Luminous
 point there is an Image at O let us en-
 quire what will be the consequences.
 Let the figure $+$ placed there, let us
 discover how its image will be reflected.
 When the Body at O is within ϵ

then nothing extraordinary

occurs. When however $+$
 it remains without O

ϵ , the Image is reflected,
 but in an inverted po-
 sition. Thus in these 2

figures we see the ϵ
 body at O shown
 in an inverted po-
 sition at the focus F



The magnitudes of the reflected
 objects that is the real object & the reflected
 Image being supposed as $m : m'$
 then we have $d : \frac{dr}{2d+r} :: m : m'$. So
 that $2d+r : r :: m : m'$.

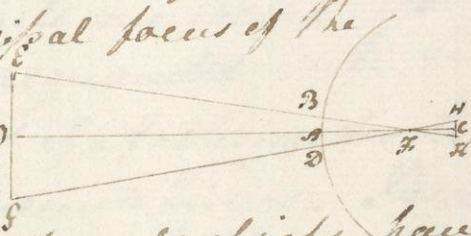
Such are a few of the properties
 of the concave Speculum we shall
 now finish Catoptrics by shortly con-
 sidering some of the properties of the

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Concave Speculum

This kind does not like the
 other magnify objects, but diminishes
 them, & more so the farther they are
 removed. The objects never appear
 in their true shape, straight lines
 are by it curved, incident parallel
 rays or such as come from very great
 distances are reflected divergingly, &
 their divergency is such that if produ-
 ced behind the reflecting surface
 they will meet at the distance of $\frac{1}{2}$
 the radius of convexity, that point
 is called the virtual focus of those
 rays & the principal focus of the
 reflector. Diver-

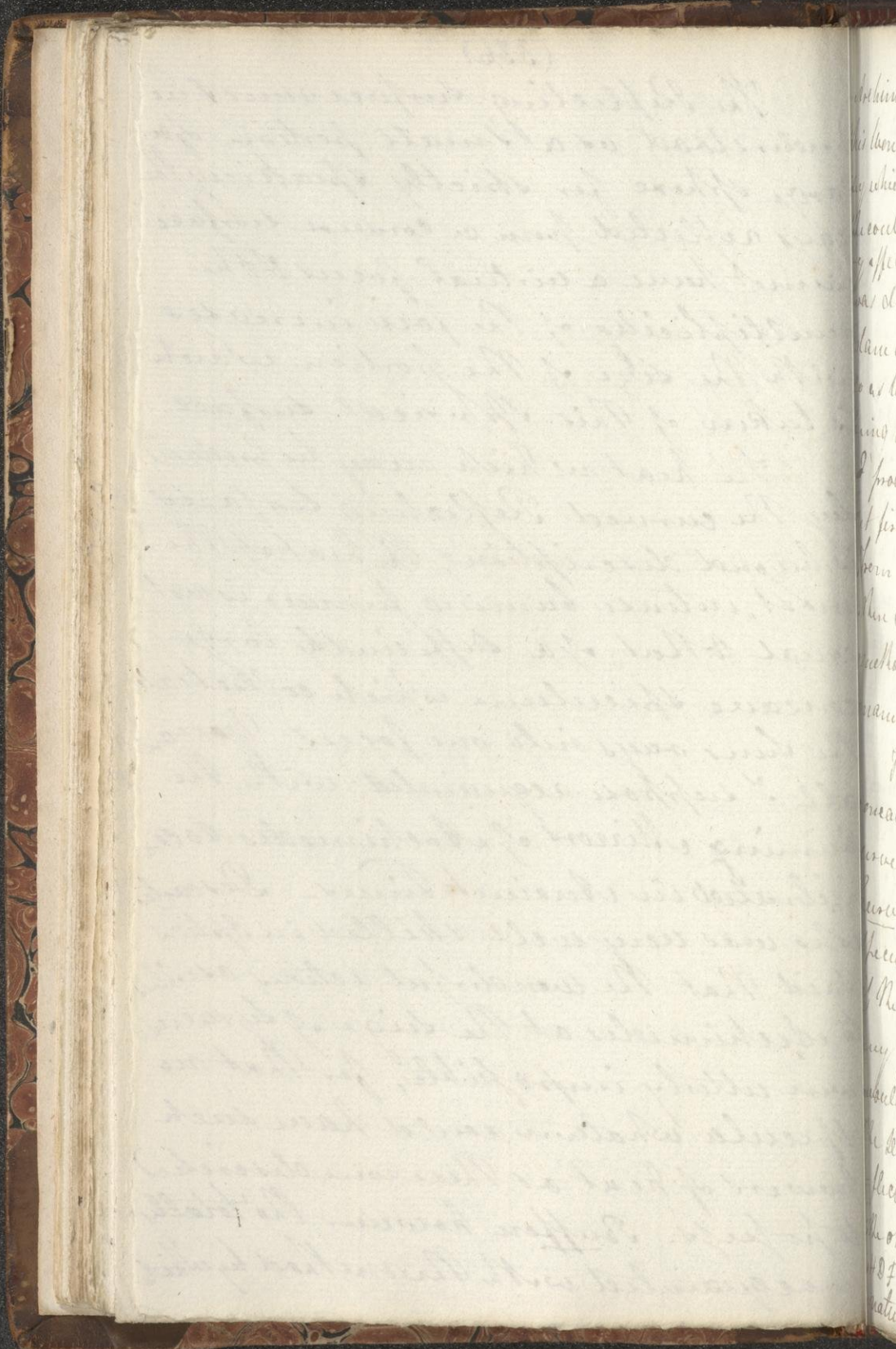
ging Incident Rays or such as
 come from near small objects have
 their virtual focus nearer to the re-
 flecting surface than half the radius.
 When the Incident Rays are Con-
 verging if the distance of the lumin-
 ous point be less than half the
 radius of convexity the reflected rays
 will have a real focus before the sur-
 face otherwise they will have a virtual one behind.



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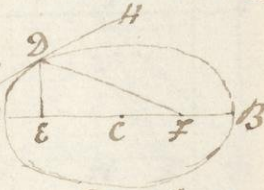
The Reflecting surface must be understood as a small portion of a large sphere for strictly speaking the rays reflected from a convex surface cannot have a virtual focus & the multiplicity of the foci increases with the size of the portion which is taken of this spherical surface.

The heat which may be produced by the curved Reflecting surfaces is beyond description; the heat of the most intense burning furnace is not equal to that of a sufficiently large concave speculum which collect all the suns rays into one focus. You are all I suppose acquainted with the burning Mirrors of Archimedes so celebrated in Ancient Times. Descartes who was very well skilled in Optics said that the wonderful actions ascribed to Archimedes at the siege of Syracuse were utterly impossible, for that no specula whatever could have such powers of heat as these were described to possess. Buffon however tho' totally unacquainted with the method by which



Archimedes was said to have performed his thunderous Jests discovered a method by which with the assistance of Glasses he could produce the most extraordinary effects at a great distance. This was done by having a number of plane Mirrors moveable on hinges so as to be directed in any way; these being all made to bear on one point, & produce astonishing heat. They set fire to Town at the distance of 100 yds. From a Greek manuscript since found there can be no doubt this was the method employed by Archimedes, the manuscript was written by Anthemius.

He says proceeding from the concave Speculum are sometimes curved which is called the Caustic Curve. If the surface of the concave Speculum are Elliptical as here then if the ray from D fell on any part of the curve it ^A would be reflected off in the Direction DF if it fell at D then reflected ray will always pass thro' the other focus. Thus making the $\triangle HDE$ & HDF . The points E & F are therefore very naturally called foci. Specula



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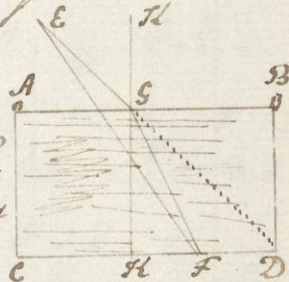
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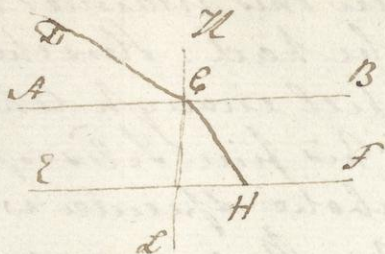
curved in this manner are very different to the last. Herschel however was successful enough to have them for some of his fine Telescopes. Particularly the Parabolic Specula which are very valuable. We come now to consider

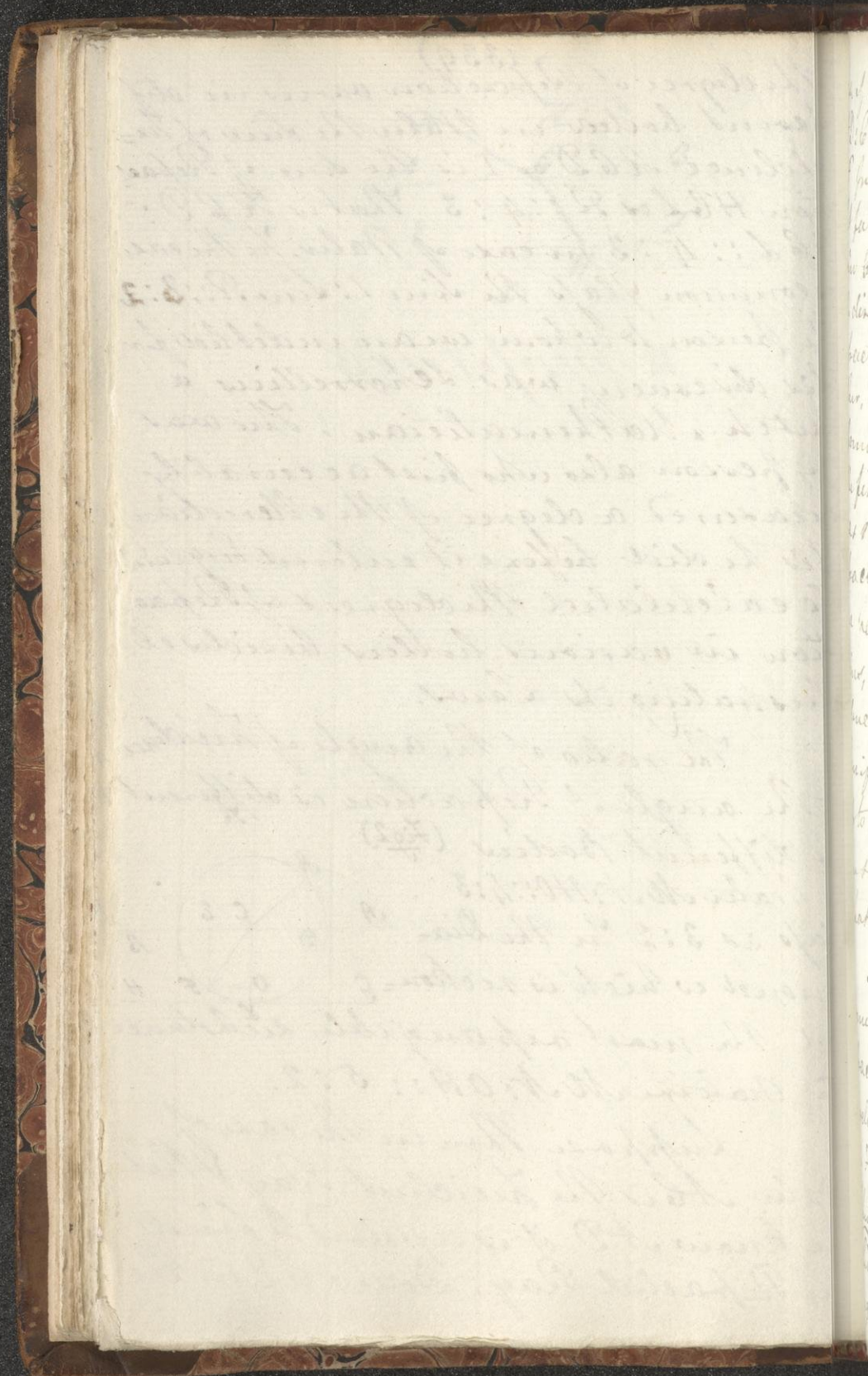
III Dioptrics

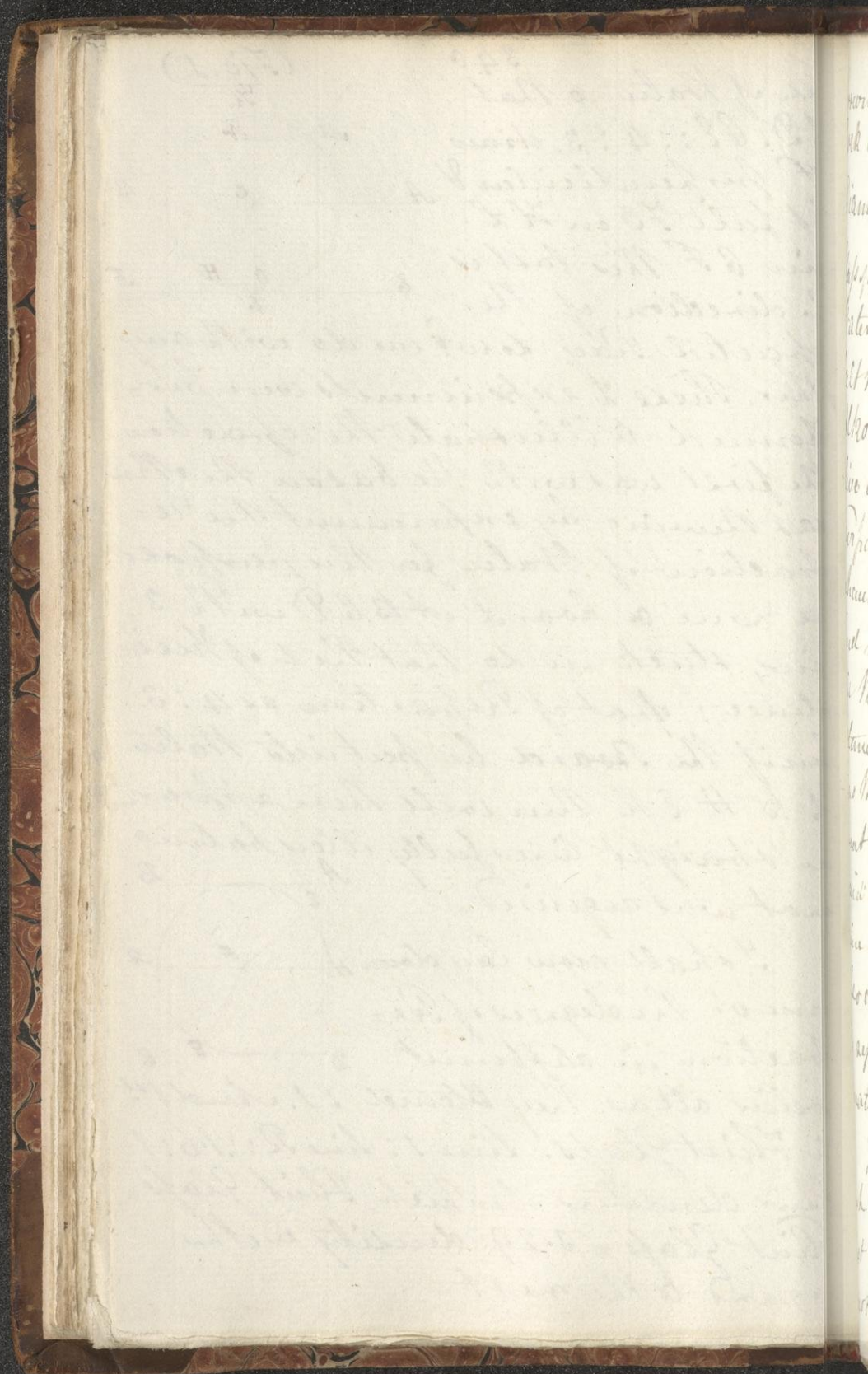
or Refracted Light. What Light passes thro', as the Air Glass Water &c. are termed the Medium of Light. Rays of Light in the same Medium always move along in straight Lines, but when a ray of Light makes a transition from one Medium to another then the Ray is bent in its course more or less according to the nature of the Medium in which it moves.

Now suppose the vessel ABCD is filled with Water & if there be some object as F it will not be seen from E in the direction EF, but it will be seen if the Eye be at C directed towards D in the refracted directions ES & SF. Draw EG perpendicular to AB & the angle of Incidence EGE is greater than that of Refraction FKH.









(34¹/₂ Refrac:)

Crown Glass :: 1.532 : 1 & 2.54^{lin}
 Rock Crystal :: 1.561 : 1 & 2.5
 Diamond { :: 2.439 : 1 & 3.54
 { :: 2.755 : 1
 Glass of Antimony :: 1.889 : 1 &
 Water = :: 4 : 3 or :: 1.336 : 1 & 1.
 Salt Water satur: :: 1.375 : 1 & .798
 Alcohol = :: 1.371 : 1 & .91
 Olive Oil = :: 1.465 : 1 &
 Turpentine = :: 1.560 : 1 & .87
 Exhausted Air pump = :: 0.999 : 1 -

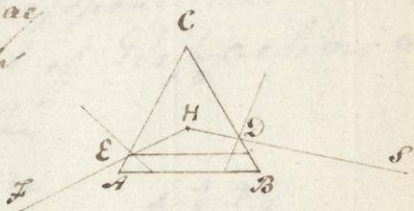
And many more might be mentioned.
 All the unctuous & inflammable sub-
 stances are most refrangible. Thus it
 was that Sir Isaac Newton from the
 great refrangibility of the Diamond
 said that this substance wd at some
 time be found to be inflammable. He
 also discovered first that Light by
 its refrangibility produces the y^{pr}is-
 matic colours.

The Refraction of Light is not
 such a simple matter as may at
 first be supposed. The refracted Ray
 is not a simple homogeneous ray but
 consists

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of 7 different rays (342)
 each a different co-
 -lour. These 7 Colours are in the order of
 least Refraction Red, Orange, Yellow,
Green, Blue, Indigo, & Violet. Red
 undergoes the least refraction, the Violet
 the greatest. These may
 be seen thro' a triangular
 piece of Glass called a
Prisme, passing thro'
 this the pure invisible



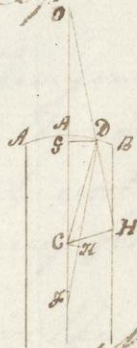
Ray is refracted & separated into these
 7 primitive colours. Thus let ABC be
 a triangular prism of Glass. The Re-
 -fracted Ray EH enters & is refracted
 in the direction HF, & according to
 the degree of Refraction are the different
 colours formed.

The History of the discovery of
 these prismatic colours forms a remark-
 -able feature in the life of Newton.
 The discovery of the Refraction of light
 was first made by Snellius a Dutch
 Astronomer, but it was Newton who
 first discovered & pointed this property
 of light separating into 7 coloured rays.
 This is a very curious property in optics
 but it is a property extremely ingenious

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to Optical Instruments, but from know-
ing it its several properties we are
enabled to guard more easily against
the injury. Suppose we have a long
cylinder of Glass terminated by a sphere
at one extremity & suppose that the line
of incidence is to that of Refraction as
 $m:n$ that is in the
figure $CH:CH::m:n$.



Suppose that $AF=x$,
 $AB=r$, & $AD=d$. Now
compare the triangles
 OBH & ODG . The $\angle$ at D
& H are $\angle$ the $\angle O$ common & therefore

the remaining angles are equal, con-
sequently they are similar $OB:OH::$

$OD:DG$ that is algebraically $Ad+r:CH::$

$d:DG = \frac{d \times CH}{d+r}$ also $DG:F$ & $H:B$ are

similar triangles therefore $EG:HB::$

$DG:CH$ or $FG:GD::BF:CH$ or alge-

braically $As x: \frac{d \times CH}{d+r} :: x-r:CH$

therefore $CH = \frac{x-r \times \frac{d \times CH}{d+r}}{x}$ or $x =$

$x-r \times \frac{d \times CH}{d+r}$ or let us suppose that

$CH = \frac{(d+r)x}{m \times CH}$ which is the case from the

supposition set out with $m:n::$

$CH:CH = \frac{m \times CH}{m}$ equate therefore the

values of CH & the Equation which

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shall trace throughout becomes then

$$\frac{n \times CH}{m} = \frac{x - r(d \times CH)}{(d + r)x}$$

$$\frac{n}{m} = \frac{(x - r)d}{(d + r)x}, \text{ or to simplify it, it is}$$

$$\frac{n}{m} \times (d + r)x = (x - r)d \text{ or by actual Multipli.}$$

$$\frac{ndr}{m} + \frac{nr x}{m} = dx - dr \text{ hence we have}$$

$$dr = dx - \frac{nd}{m}x - \frac{nr}{m}x$$

$$dr = (d - \frac{nd}{m} - \frac{nr}{m})x \text{ Therefore}$$

$$x = \frac{dr}{(d - \frac{nd}{m} - \frac{nr}{m})} \text{ This then is the}$$

final value of x in which value rests the foundation of the many properties of Lenses.

If we suppose that in the figure above O is infinitely removed then this value will be different & will become equal to

$$\frac{dr}{d - \frac{nd}{m}} \text{ or } x = \frac{r}{1 - \frac{n}{m}} \text{ This then is the simple}$$

formula which expresses the focus of parallel Rays in all Lenses whatever or it may be expressed $x = \frac{mr}{m - n}$ or the most simple expression of all we say $x = \frac{3r}{1}$.

These different expressions you must remember as being of great importance.

Before I proceed to the consideration of these spherical Glasses called Lenses I must recall for a moment your attention to some of the properties of the Refraction of light just gone over. 1st When a Ray EF falls upon a surface

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AB is refracted in the direction FB it
always goes out again

in a direction parallel
to that in which it

entered. The same

is the case with a

curved surface such

as a double convex lens.

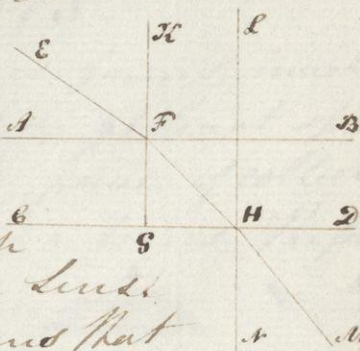
It sometimes happens that
there is no Refraction when the Ray
is Reflected. This may frequently hap-
pen from the different positions of
the Reflecting Ray -

The Rays of light when passed
thro' a prism present beautifully the
of Irisnatic colours. Supposing the
amount of all to be equal to 360

The proportions which they severally
bear to each other are nearly as
follows see figure. This discovery
alone were sufficient to immor-
talize the name of Newton.

It is a very curious coincidence
that the proportions just stated
should correspond exactly with
the Musical Notes or the Lines
Octave as it is called. This

however is a mere accident for Newton
might just as well have picked up any other numbers



Violet	80
Indigo	48
Blue	60
Green	60
Yellow	48
Orange	27
Red	45
	360

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Lenses-

These are of various forms, made of Glass, Vitr. some portion at least spheri-
-cal. They have the power of collecting
the Rays of light into a focus. The following



are some of the figures of these Lenses.

The 1 is a double Concave Lens being
concave on both sides: 2 is a Plano
Concave being concave on one side &
plane on the other. 3 is a Convex or
double Convex being convex on both
sides. 4 is a Plano Convex. The 5 is
the Miniscus being convex on ^{one} both
sides, & concave with a larger radius
on the other. Spectacles are frequently
made of this kind. In every Lens
there is a point thro' which if rays pass
their direction is in no way altered.
In every other point however rays
passing thro' are more or less bent
in their directions - Thus let there
be two concave lenses and let their
centres be joined let CD which lies
between them be so divided as that

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$BD : BC :: ED : AB$ the incident ray
after falling on FB at F

being refracted in the
direction FG is sent out
again in a direction
 GH parallel to its in-
cident direction.

Compare the triangles
 AFB & EDG they are

evidently similar therefore

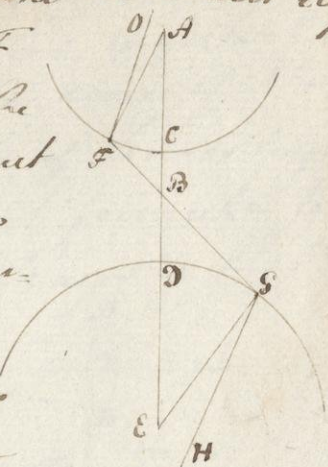
$AB : AF :: EB : EG$ or $AB : AE ::$

$EB : ED$ or $AB : BE :: AE : DE$. From

this proposition many important
properties in Optics are derived.

This has been very ably illustrated
by the late celebrated *Vinguenius*,
Dr Simpson.

I now proceed to consider the
application of Lenses to 2 of the
most wonderful objects with
which Man is acquainted. The
one is the production of Nature
in the Eye, the other the noblest
best of Human Genius the
Telescope —



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Previous to entering on the consideration of Telescopes, we shall particularly examine some of the principal properties of Lenses single & combined. The great formula for the Focus of all the Rays is that x which is equal to FD is equal to



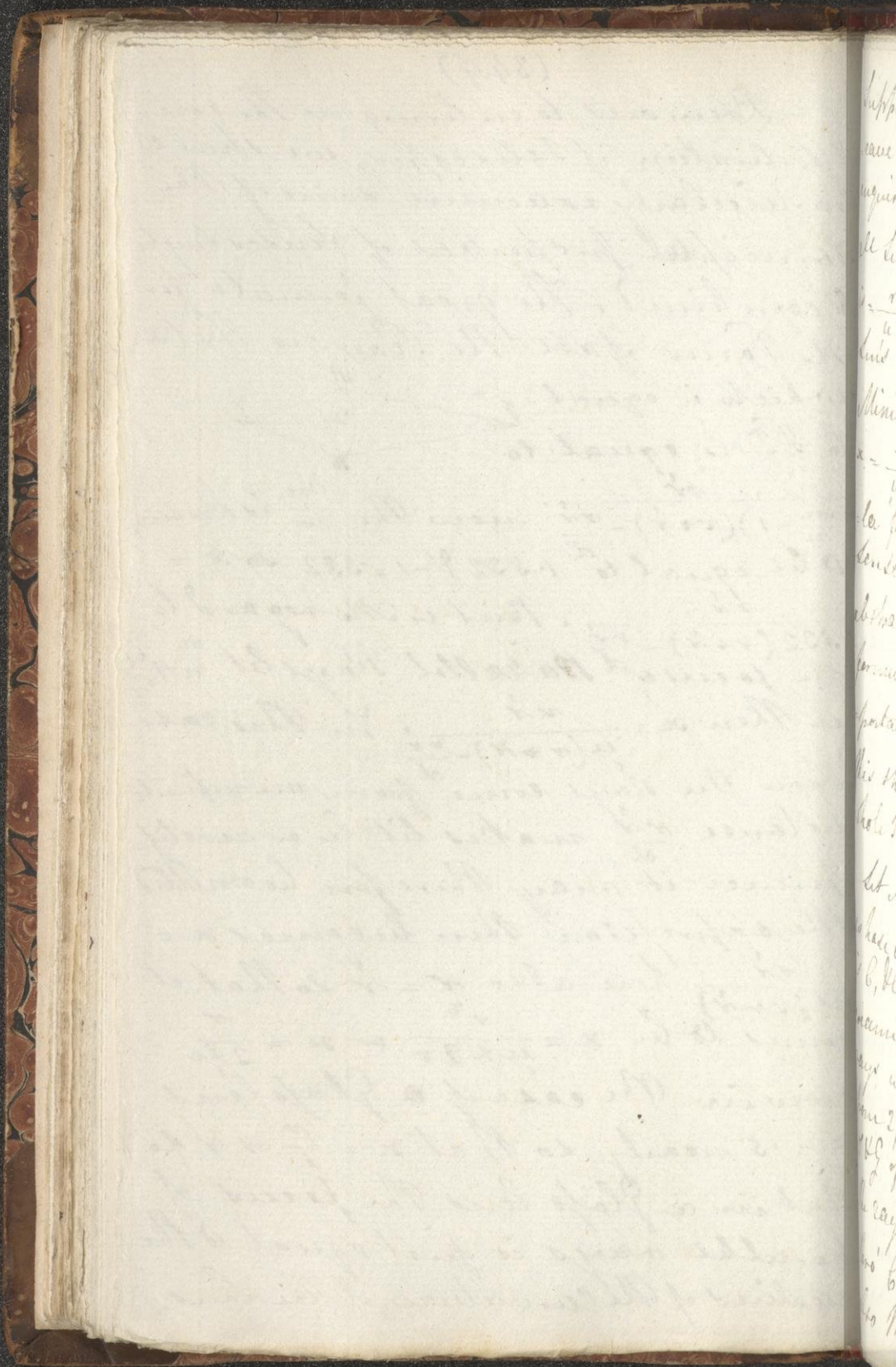
$\frac{r\dot{r}}{(u-1)(r+\dot{r})-\frac{r\dot{r}}{d}}$ now the $\frac{m}{n}$ is known & is equal to 1.532 & $1-1=.532$ so $x =$

$\frac{r\dot{r}}{.532(r+\dot{r})-\frac{r\dot{r}}{d}}$. But wth regard to the focus of d Parallel Rays let $\frac{m}{n}=1$ then $x = \frac{r\dot{r}}{u(r+\dot{r})-\frac{r\dot{r}}{d}}$ In this case

when the Rays come from an infinite distance $\frac{r\dot{r}}{d}$ makes little or no difference it may therefore be omitted & the expression then becomes $x =$

$\frac{r\dot{r}}{u(r+\dot{r})}$ here also $r = \dot{r}$ so that it comes to be $x = \frac{r^2}{u \times 2r}$ or $x = \frac{r}{2u}$

now in the case of a Glass lens $u = 1.5$ nearly so that $x = \frac{r}{1.5}$ or r so that in a Glass lens the focus of parallel rays is just equal to the radius of the curvature of the Lens.



Suppose the lens is a plane concave into whose properties we are enquiring then $x = \frac{r \dot{r}}{u(r + \dot{r})}$ for in all lenses the focus of parallel rays is $= \frac{r \dot{r}}{u \dot{r}}$. If we take a concave lens then $x = \frac{r \dot{r}}{-u(r + \dot{r})}$ & $x = \frac{r}{-2u}$. In the Miniscus there is some difference $x = \frac{-r \dot{r}}{u(r + \dot{r})}$ Such then are the formulae for the radii of the different lenses. This indeed is merely an abstract point in algebra as all formulae are, giving us very important general expressions. In this short consideration almost the whole Theory of Lenses is included.

Let AB be a double convex lens.

whose centre

is C , & let us

examine the

rays which

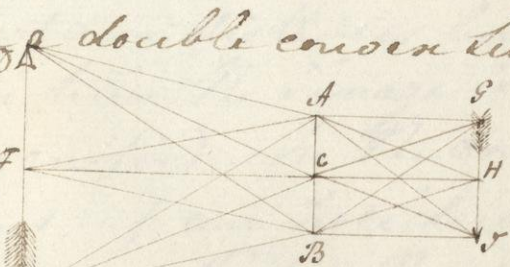
pass from 2 points

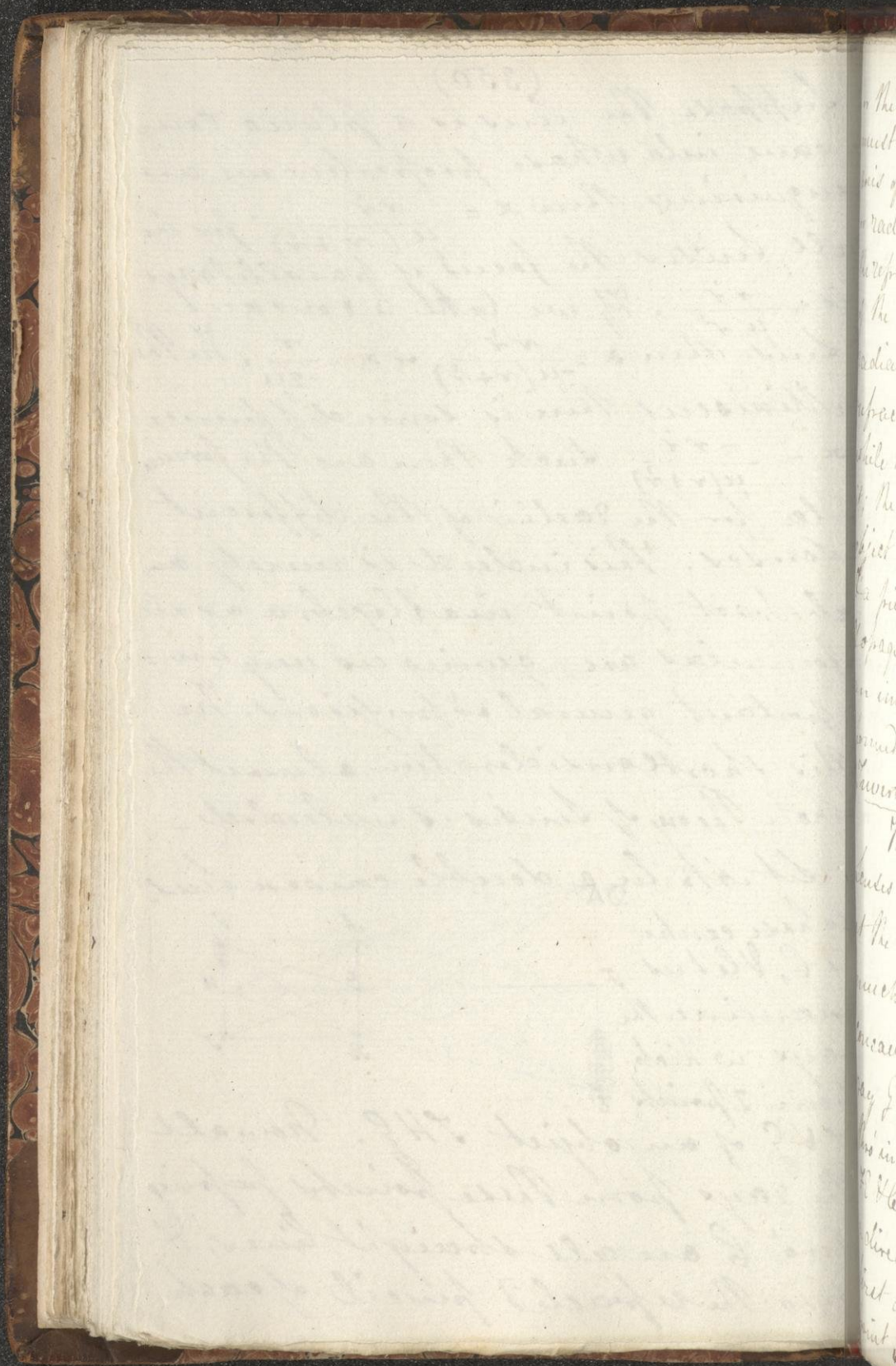
S & G of an object SHG . Now all

the rays from these points passing

thro' C are all straight lines, &

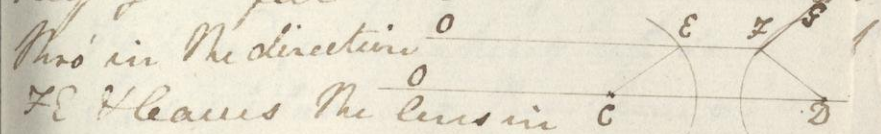
also the refracted pencil of each





or the refracted focus of each pencil must be on the contrary side of the axis of the lens to what its incident or radiant focus is, for instance the refracted focus F is below the axis of the lens while its incident or radiant focus D is above it & the refracted focus G is above the axis while the radiant point E is below it; the consequence of which is if the object DE be sufficiently luminous th a piece of white paper or other glassy, opaque body, at GF be placed, then an image of the object DE will be formed on it but it will have an th Inverted position.

This holds invariably in all lenses at certain distances, but at the same time the image is too much magnified. In the double^d concave lens, if an incident ray GF fall on F it is thus refracted th in the direction FE & leaves the lens in C a direction EC parallel to its first direction; if however the point F is infinitely removed it is



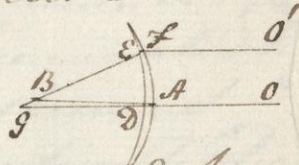
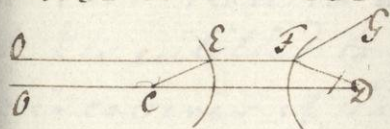
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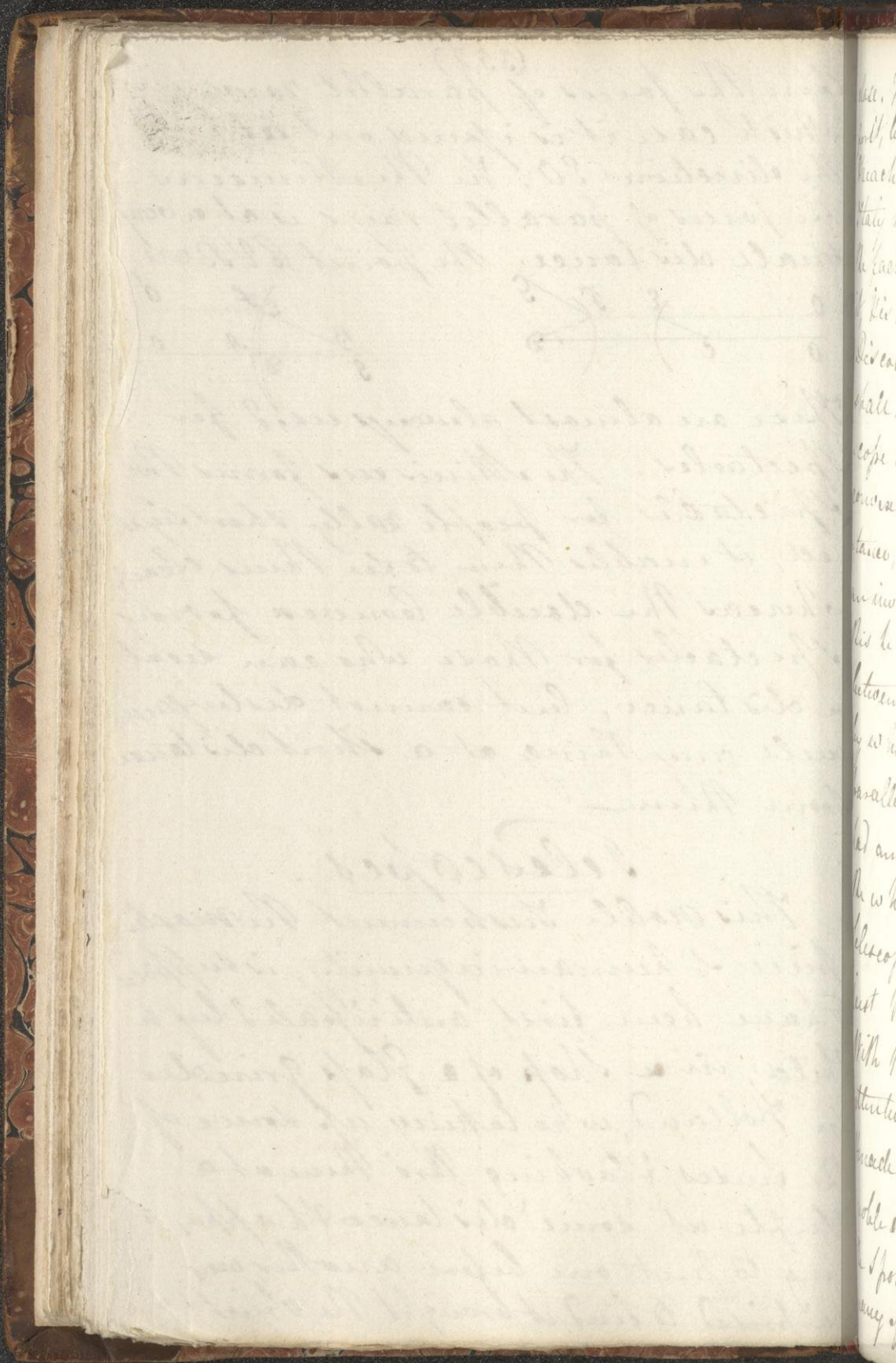
Then the focus of parallel rays, in which case it is issued out at E in the direction EO . The Miniscus the focus of parallel rays is at a very small distance. The point C & D are



These are almost always used for spectacles. The Miniscus forms the spectacles for people really short sighted, it enables them to see things clearly whereas the double convex forms spectacles for those who can see at a distance, but cannot distinguish well any thing at a short distance from them—

Telescopes

This noble instrument the masterpiece of human ingenuity, is supposed to have been first anticipated by a child, in a shop of a glass grinder in Holland, who taking up some of the lenses, & looking thro' them at a spectacle at some distance & happening to put one before another was surprised to find it brought the object



case. The Man was unable to account
 for it, but it was soon noised abroad.
 Reached the ears of Galileo. Then in
 Italy he no sooner had examined
 the said Man in a short time he explained
 it, & is entitled to be denominated the
 Discoverer of this Instrument. I
 shall now explain his simple Tele-
 scope it consisted first of a double
 convex lens of considerable focal dis-
 tance, this he found magnified with
 an inverted Image however, to remedy
 this he placed a double concave Glass
 between the convex Glass & the focus
 by which he brought the rays in a
 parallel direction & at the same time
 had an erect image. This then is
 the whole principle of the Galilean
 Telescope, & as you may observe is
 just the principle of our Opera Glasses.
 With this simple Instrument he
 attentively viewed the heavenly bodies &
 made by means of it some very
 noble discoveries. By it he discovered
 the spots on the Sun's face, & also
 many of the phenomena of Venus.



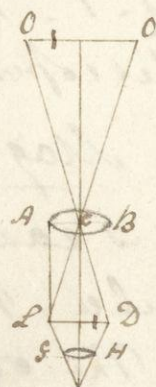
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The Astronomical Telescope differs very little from this in principle. The double concave is not placed before the rays of the convex come to a focus & form their inverted Image  but another convex is placed beyond this at C H & thus the rays are thrown out parallel.  On this various improvements have been made, this is but the very simplest form of the Astronomical Telescope as constructed & employed by Galileo.

Considering the Subject of Telescopes we may divide into 2 divisions. 1. The Magnifying power of Telescopes & 2. The Extent of Vision.

1. Magnifying power of Telescopes.

This is easily determined by a simple formula. We have here an Image F E of the object at O O' which then comes upon a Lens S H. Now we say as L F E L : F H L :: e L : F E That is



to say the angle $\frac{FHL}{FCL} = \frac{CL}{FL}$. Wherefore
 if we divide the focal distance of
 the Eye Glass by the focal distance of
 the other Glass we gain the Magnifying
 power of the Telescope. Suppose FL
 were equal to 1 inch & that $CL = 120$ feet
 then the Magnifying power wd be
 120 inches - The Telescope then Mag-
 nifies 120 times - This is a formula
 by which we may at all times de-
 cide, calling x the Magnifying power
 then the focal distance of the Eye
 Glass, or that of the other, then we
 have always as a general expression
 $x = \frac{m}{n}$. The next consideration is the

2. Field of Vision

This is the extent to which while
 looking thro' a Telescope we can
 see around us, now if we suppose
 that there is an object O to be seen
 thro' the 2 Lenses AB & GH if P is
 we call the focal distance of the
 Eye Glass F that is the focal distance
 of AB , & that of GH - f then we have
 as $F + f : f :: A - a : \frac{(A - a)f}{F + f}$ This then
 expresses the value of $L.F$ to this a
 must

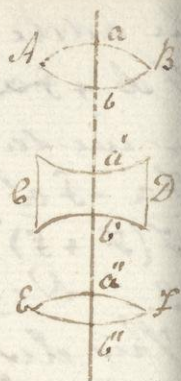
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be added. You have $a + \frac{Af - af}{f}$ or
 $f + \frac{a}{f} - \frac{af}{f} = f + \frac{a}{f} - a$ then $fL = \frac{f + \frac{a}{f} - a}{f} = \frac{f + \frac{a}{f} - a}{f}$
 or in the Tang. in the field of vision =
 $\frac{f + \frac{a}{f} - a}{f}$. We shall consider lastly
 $f(f + \frac{a}{f})$

3. Distinctness of Vision

This distinctness, or illumination
 of the object is very different in differ-
 ent Telescopes has considered of
 much advantage when of a high
 degree. $A^2 : p^2 :: m^2 : 1$ then $\frac{A^2}{m^2} : p^2 :: f : i$
 therefore $f = \frac{A^2}{m^2 p^2} \times i$. This is the
 Formula -

The greatest discovery which
 has been made in Optics since
 the time of Sir I. Newton is undoubtedly
 that of the Grand Achromatic Teles.
 This consists of 3 Lenses two con-
 -cave made of the Flint Glass &
 one concave of the Crown Glass. These
 combined form a perfectly colourless
 Image. It is impossible to conceive
 any thing more ingenious than this
 combination of Lenses. This has
 sometimes been termed the triple ob-
 -ject Glass. The Flint Glass is specific-
 -ally heavier than the Crown.



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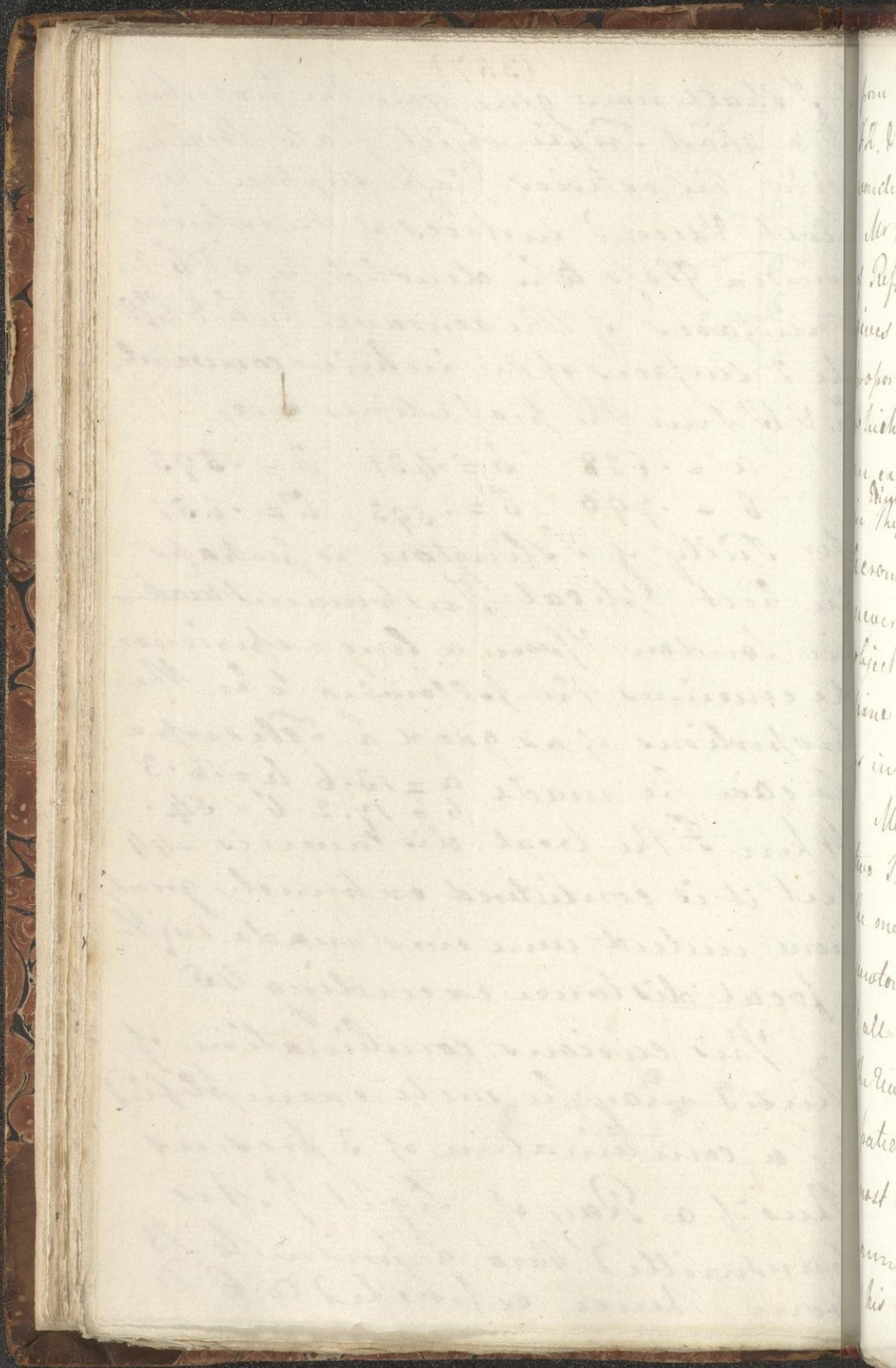
I shall now give you the proportions of a good Triple object Glass. Beginning with the exterior Glass suppose the first & second surfaces of the exterior convex Glass to be denoted by a & b , the 2 surfaces of the concave by a' & b' , & the 2 surfaces of the interior convex a'' & b'' then the proportions are

$$a = .628 \quad a' = .431 \quad a'' = .593$$

$$b = .790 \quad b' = .593 \quad b'' = .651$$

Mr Tully of Tlington is perhaps the best Optical Instrument-maker in London. Upon a long experience he conceives the following to be the proportions of a good 2^d Telescope as also he made $a = 13.6$ $a' = 16.3$
 $b = 17.2$ $b' = 54$.
 When the focal distance is = 44. but it is considered extremely great, none indeed were ever made with a focal distance exceeding 45.

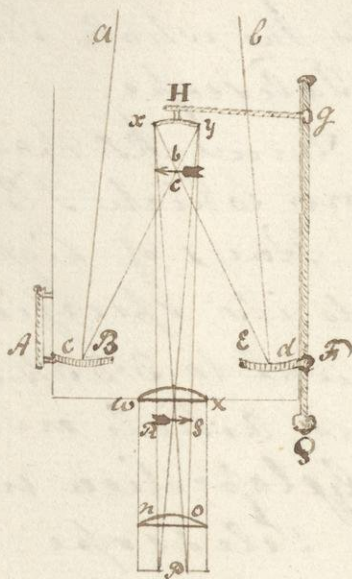
This curious combination of Surfaces may be well exemplified by a combination of 3 prisms - Thus if a Ray of Light $P.A$ is transmitted thro' a prism ABC from thence refracted to $C.D$.



from D to E, from F in the direction
F H, & this is the whole Theory of this
wonderful Telescope.

Mr Tully remarks that the degree
of Refraction which Flint Glass
gives to the Rays of Light is in
proportion to its Specific Gravity,
which is equal to 3.354. There is
an excellent article on the subject
in the ^{English} Encyclopaedia under the
Astronomic Telescope. Newton
never supposed that the colored
object which Telescopes in his
time produced could be remedied
as in the Telescope before us.

Much about the same time
two Telescopes were invented
the one by Gregory the other by
Morton. Gregory was the Master
of all that approached nearer
the rival of Newton. He antici-
-pated him even in many of his
most noble discoveries. We shall
commence with the consideration
of his Telescope, & called after him
the

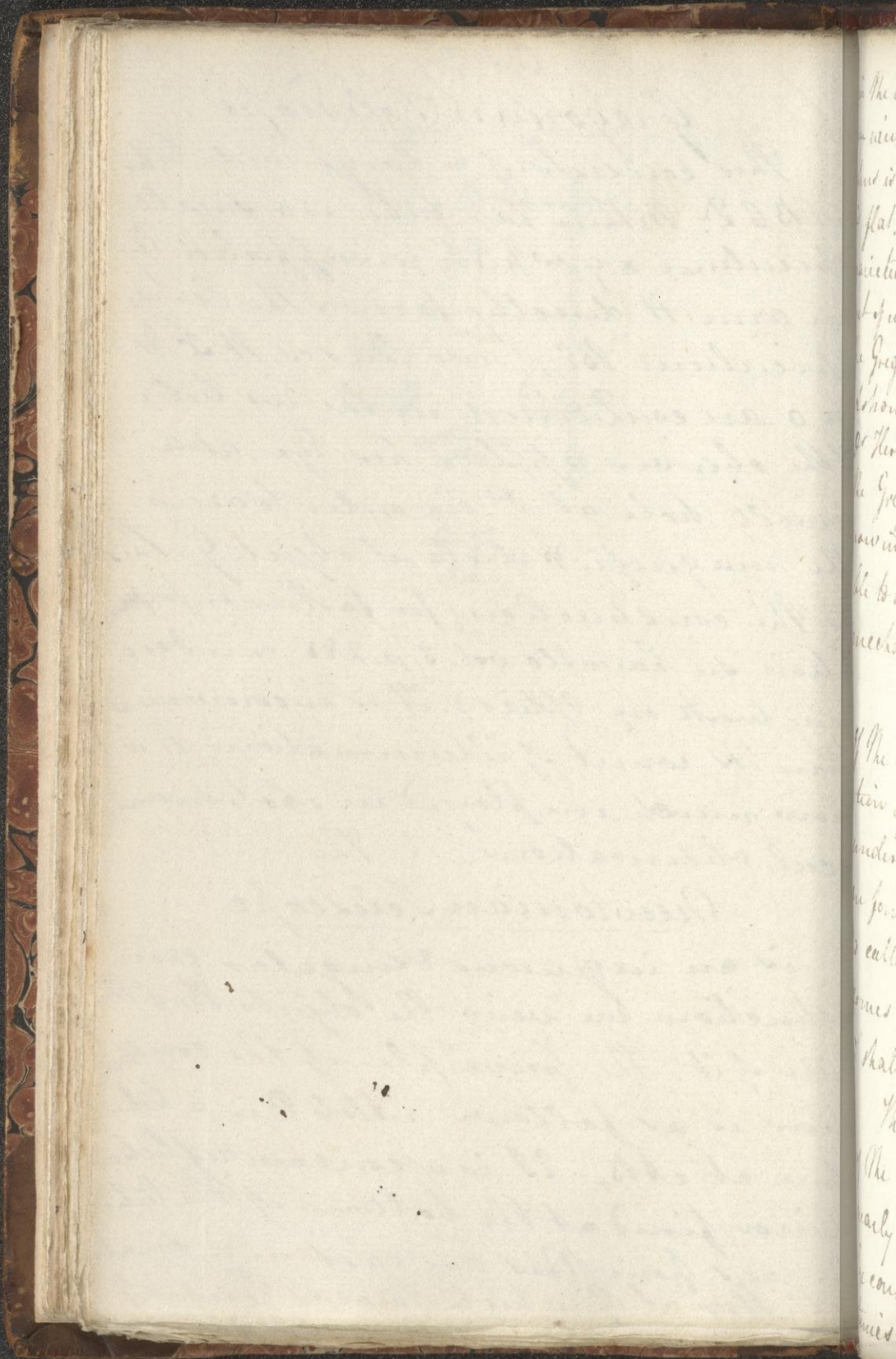


Gregorian Telescope.

This consists of a large wide tube $ABCD$. Within this tube is a small speculum xy which is supported by an arm H directly facing the large speculum BE . Two Lenses W & X are contained in the Eye tube & the observer applies his Eye at a small hole at P in order to view the magnified distant object G . This is the construction (for farther improvement see Cavallo vol. 3. p. 285, or indeed any work on Optics) It is inconvenient from its want of illumination. It is now much employed in astronomical observations. The

Newtonian Telescope

is an ingenious & singular construction we view the objects thro' the side of it. The principle of the construction is as follows $ABCD$ is a tube open at AB , EF is a concave reflecting mirror fixed at the bottom of the tube the rays from this are cast on a small reflector at G which throws them off



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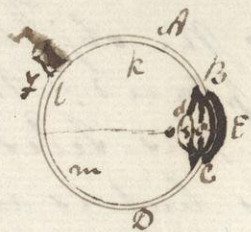
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in the direction of L at which point we view the objects, near L another lens is placed; The Speculum at G is flat. This Telescope has many varieties but is now almost entirely out of use, & was thrown aside before the Gregorian, which is used by all Astronomers in their observations. Dr Herschel's best Telescopes are of the Gregorian principle. I mean now in as brief a manner as possible to consider the construction & mechanism of the human

Eye -

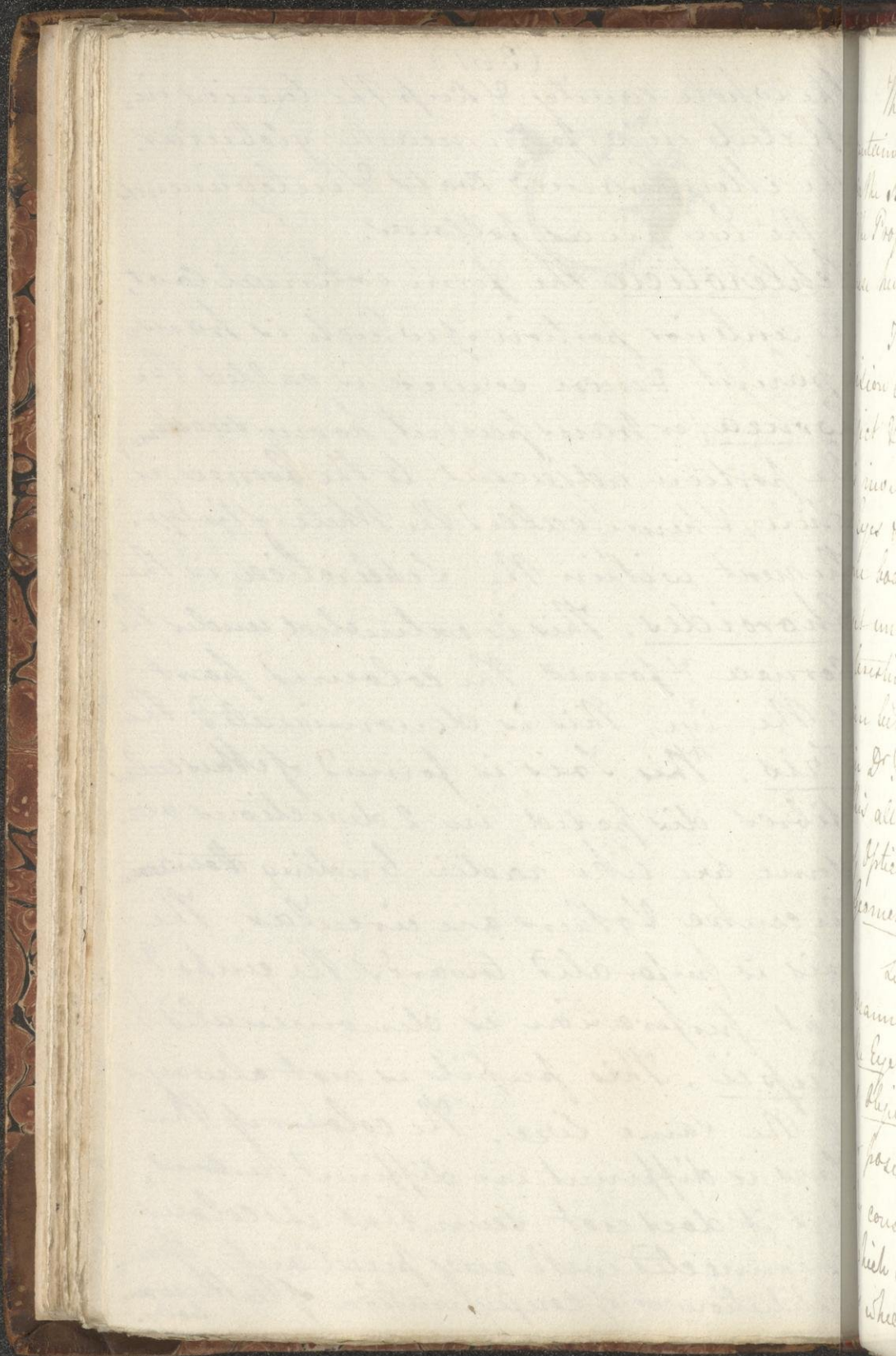
Of the 5 external senses the construction of the Eye seems to be best understood. The Images of all things are formed within the Eye on what is called the Retina. How this comes to be formed & how we see it, I shall now explain -

This figure represents a section of the Human Eye. The figure is nearly Globular, The bulb of the Eye consists of external coats or tunics internal humours that fill



The whole cavity & keep the tunics inflated in a form nearly globular. The Membranes coats & Integuments of the Eye are as follows.

Sclerotica the firm external coat, the anterior portion of which is transparent & more convex is called the Cornea (or transparent horny substance) the portion adjacent to the Cornea is white, & hence called the White of the Eye. The meat within the Sclerotica is the Choroides. This is extended under the Cornea & forms the coloured part of the Eye, this is denominated the Iris. This Iris is formed of Muscular fibres disposed in 2 directions viz. some are like radii tending towards the centre & others are circular. The Iris is perforated towards the centre & that perforation is denominated the Pupil. This pupil is not always of the same size. The colour of the Iris is different in different persons, but it does not seem that its colour is connected with any peculiarity of constitution or of configuration of the Human body.



The above mentioned Membranes contain their different kinds of humours, viz the Aqueous, Crystalline & Vitreous (The Professor here gave us an account of these humours & farther detail on the Eye)

Two very curious facts regarding Vision are. **I.** That we see an erect object & at the same time the Image is inverted on the Retina. **II.** That with 2 Eyes & therefore 2 Images we only see one body. These are 2 very curious & yet unaccountable facts. On this interesting subject there is no book. I can better recommend that the Chapter in Dr Reid's Enquiry, on this Subject. This all who wish to have a knowledge of Optics sh^d consult. It is entitled The Geometry of Visibles.

Let us now enquire into the manner in which Men judge by the Eye of the position & appearance of objects. 1. We judge of distance or position of an object from the Eye by considering the Optical Angle, which it presents; The greater the angle is which it subtends the nearer is the

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object to us vice versa. This is the method which every one naturally follows in judging of distance, it is also a very sure method; it is well exemplified by the Surveyor or Sailor, who by practice can judge very accurately. The second ^{2nd} is by considering the Distinctness of the Outline. This is also an obvious & very good way. There is a third method which however does not occur so naturally to ordinary men as to Painters ^{3rd} Light & Shade. This to those who understand it is an infallible method by which to judge of the position of Rocks. And by a good Eye this has been distinctly discerned at Mountains 4.0 Miles distant. All these methods however w^d be entirely useless had we not the power of Motion. There is another circumstance to which I must draw your attention which is this.

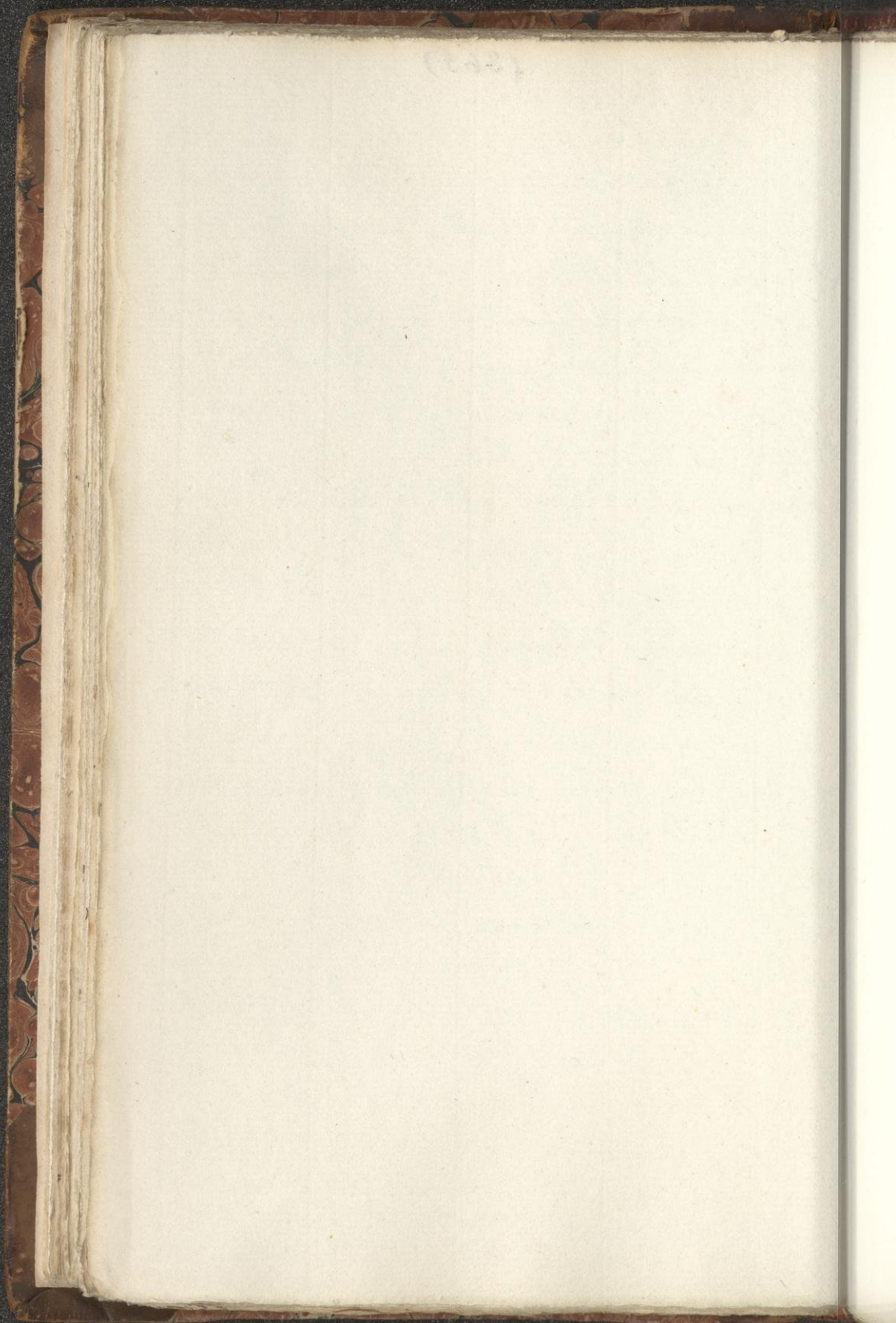
Suppose we are moving along the line CD from C to D & there are 2 objects A & B , then as we advance the $\angle BDA$ is always increasing to a certain point, now it



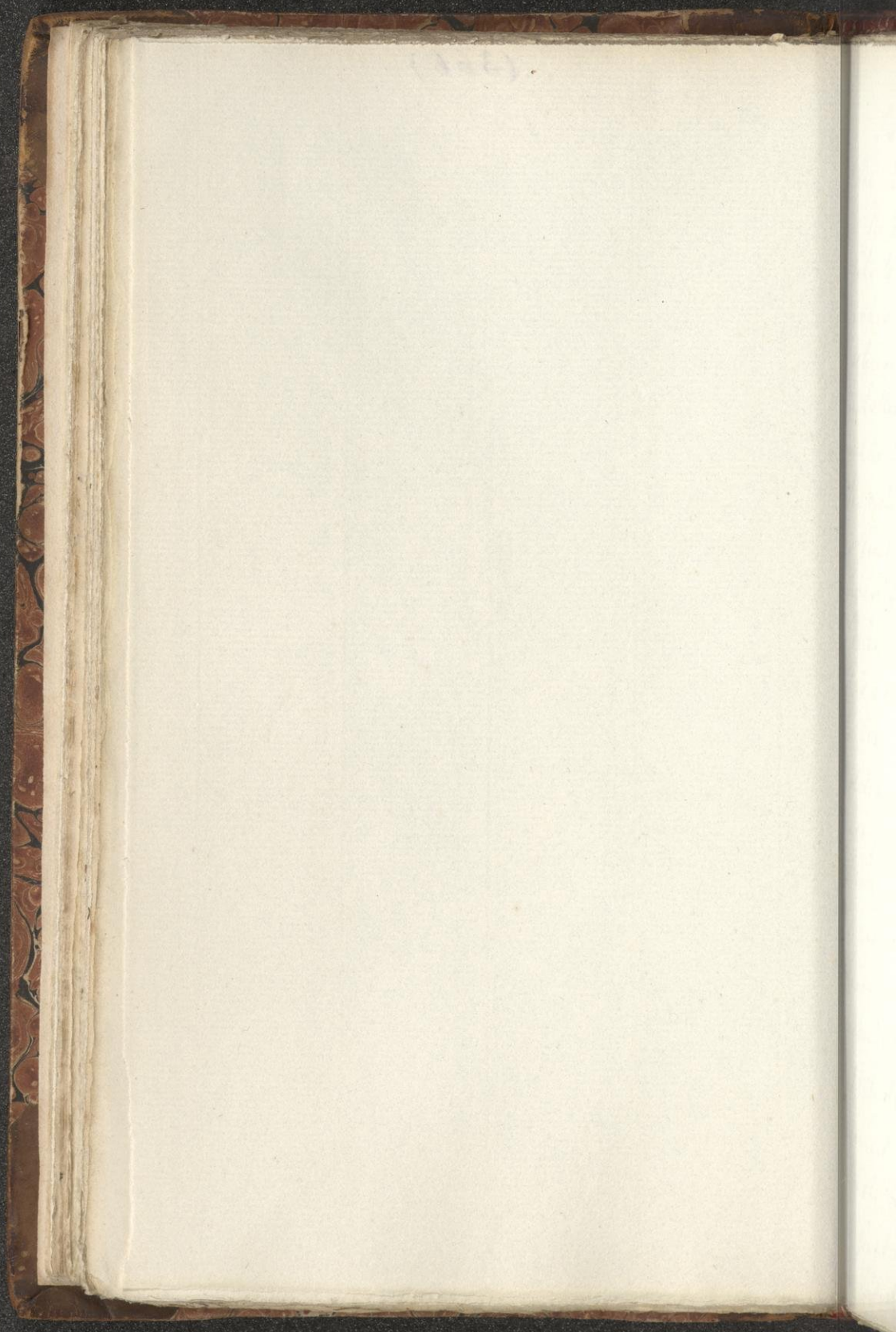
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it may be asked which of these 2 objects are
 we to suppose nearest to us? it is that
 which appears to move along with us.
 This is what you may frequently have
 observed in distant objects, such as the
 Moon which appears to move with us,
 she also appears much larger when
 she rises than when on the Meridian.
 This is called the Phenomenon of the
Horizontal Moon. It is caused by the
 multiplicity of objects, for if we look
 at her when she is rising at a thin at
 the Meridian thro' a Telescope or even
 a tube she still appears of the same size.
 We are frequently deceived in the size of
 objects by thus judging erroneously of
 their distance. This once occurred forcibly
 to me in the Highlands. Standing near
 on the side of a Loch (about 11 or 12 at night)
 I thought the Hills around remarkably
 low the highest not exceeding Arthur's
 Seat, but when I came to the mountain
 rising I discovered my mistake & found
 one of them to be a Mountain 3000 of height.
 so much was I deceived; for having
 supposed myself some distance from them
 I was surprised in the morning to find myself
 at their foot.

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I shall now consider the phenomenon of the Rainbow. This appearance in the Heavens is always directly opposite to the Sun & consists of 2 bows or Arches the one the Interior the other the Exterior Bow. The former is, $2^{\circ}.15'$ broad the latter $3^{\circ}.15'$ & being a little apart they make together a breadth of about $4^{\circ}.5'$. The order of colours in the Rainbow is just that of the prism (p.) but inverted, the Red uppermost &c. The Interior appears below the Exterior one. It is a curious fact that the Arch which the Rainbow makes with the Horizon added to that of the Sun's altitude, also just make $42^{\circ}.17'$. So if there is a Rainbow at Sun rise its altitude is just $42^{\circ}.17'$, & if there is one when the Sun is elevated $42^{\circ}.17'$ then it is dem. nearly touching the Horizon. Thus the altitude of the one is just the complement of $42^{\circ}.17'$ to the other. Now the whole diameter of the Celestial Sphere is just double, so that the Semidiameter or Radius is just equal to $42^{\circ}.17'$.

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The first who considered the phe-
 nomenon of the Rainbow. Who la-
 boriously endeavoured to account
 for its different appearances was
 Antonio de Dominis Bishop of
 Spelatro. He demonstrated that
 it was the Refraction of the Sun's
 Rays on the drops of Rain, being
 that it never occurred but when
 there was rain in the opposite quar-
 ter of the Heavens from the Sun.
 Descartes next illustrated its
 properties, & being an excellent Opti-
 cian demonstrated clearly that
 it was the result of a double Refraction
 & a single Reflection. The complete
 illustration & explanation of this
 phenomenon was left for Sir Isaac
 Newton, & upon the great discovery
 of the prismatic colours which he
 made, it followed immediately what
 was the real cause of the Rainbow.
 He also explained the cause of the
 altitudes of the Sun & Rainbow
 making

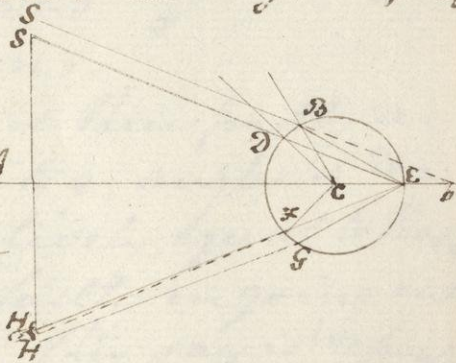
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making just $42^{\circ} 17'$. Let us now en-
deavour to reconcile these appearances
of the Rainbow with the properties of
Optics already considered. I must
premise that every one does not see
the very same identical Rainbow.
The change of position renders it dif-
ferent.

The cause being the rays
of the Sun falling on drops of Rain.
Let us then consider what particularly
happens when a ray of Light falls
on a drop of Rain. Let FGP repre-

sent a drop of
Rain, SD is a ray
of the Sun's Light, A
this from the re-
fraction does not
go straight to C ,
but is refracted

towards E . Here part is thrown
into the Air & part is refracted
again to F , & is cast out in the
direction HH not Fh . A 2^d ray
 $P'B$ is refracted in the same manner,
& thus the rest form the 7 prismatic
colours as they appear to us. If
we call the angle of Incidence x ,



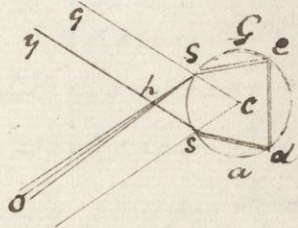
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of Refraction y . Then $x = 2y$ now $m:$
 $n :: \text{Sine } x : S. y$ from which we find
 $x = \frac{\sqrt{4n^2 - m^2}}{n\sqrt{3}}$

Such is the case with the
Interior Bow, the Exterior is more
 complicated. In the former there are two
 Refractions & one Reflection, in the latter
 2 Refractions & 2 Reflections. Let d & G P
 be a drop of Rain, y S is a ray of
 light which enters
 it as S instead of
 proceeding straight
 towards d is reflected
 towards the perpen-



-dicular Sb ; it is then partly re-
 -fracted from d to e , angles of re-
 -fraction respectively equal to those
 of Incidence. Lastly on going out
 of the drop at G this ray is refracted
 from the perpendicular gc & is
 dispersed into the coloured rays at
 O . Connected with the Rainbow
 is the Halo. This is a circle which
 surrounds the Moon & sometimes
 the Stars in hazy weather. This
 has been considered as a very
 complicated phenomenon the one

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frequent occurrence. Some have supposed it owing to Ice or Aqueous particles in the atmosphere. This in hazy weather may be seen formed around Candles or Lamps. If a persons Eye happen to have more moisture than usual in it, as may often happen in a thick raw night this phenomenon is always presented. Many therefore have accounted for it in this way; it is however owing to the aqueous viscidles that float in the Air during foggy weather.

We have already mentioned what are the proportions of the colours in the prismatic spectrum; now if we suppose these placed in a wheel some curious properties result. These were principally the observation of Sir Isaac Newton. If this wheel be rapidly turned round its centre then the whole border will appear of a white colour. From this it has been remarked that if



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You mix by weight such proportions exactly you will produce a White.

If we mix parts of them for instance

O R & V is 27, 45, & 80 = 152 This then

76 counted from either end

will mark the prevailing tint or

the centre of Gravity as it were. It

will then be of a purple. If the

colours are opposite as the O & V

then we find the centre of Gravity

by joining their centres & finding

the centre of Gravity of a line O & V

supposed to have weights propor-

tional to 27 & 40 on the ends. This

is at B & drawing the line from the

centre C thro' it gives the tint, here

it is slightly purple or violet. If

any colour is left out it is called

a complementary for by its ad-

-dition the White is formed -

Respecting Colours there remain

yet to be considered what are called

the Accidental Colours. This was

a circumstance first observed

by the French Officers. It is this

if we lay any colour such as

Red on a white ground, after

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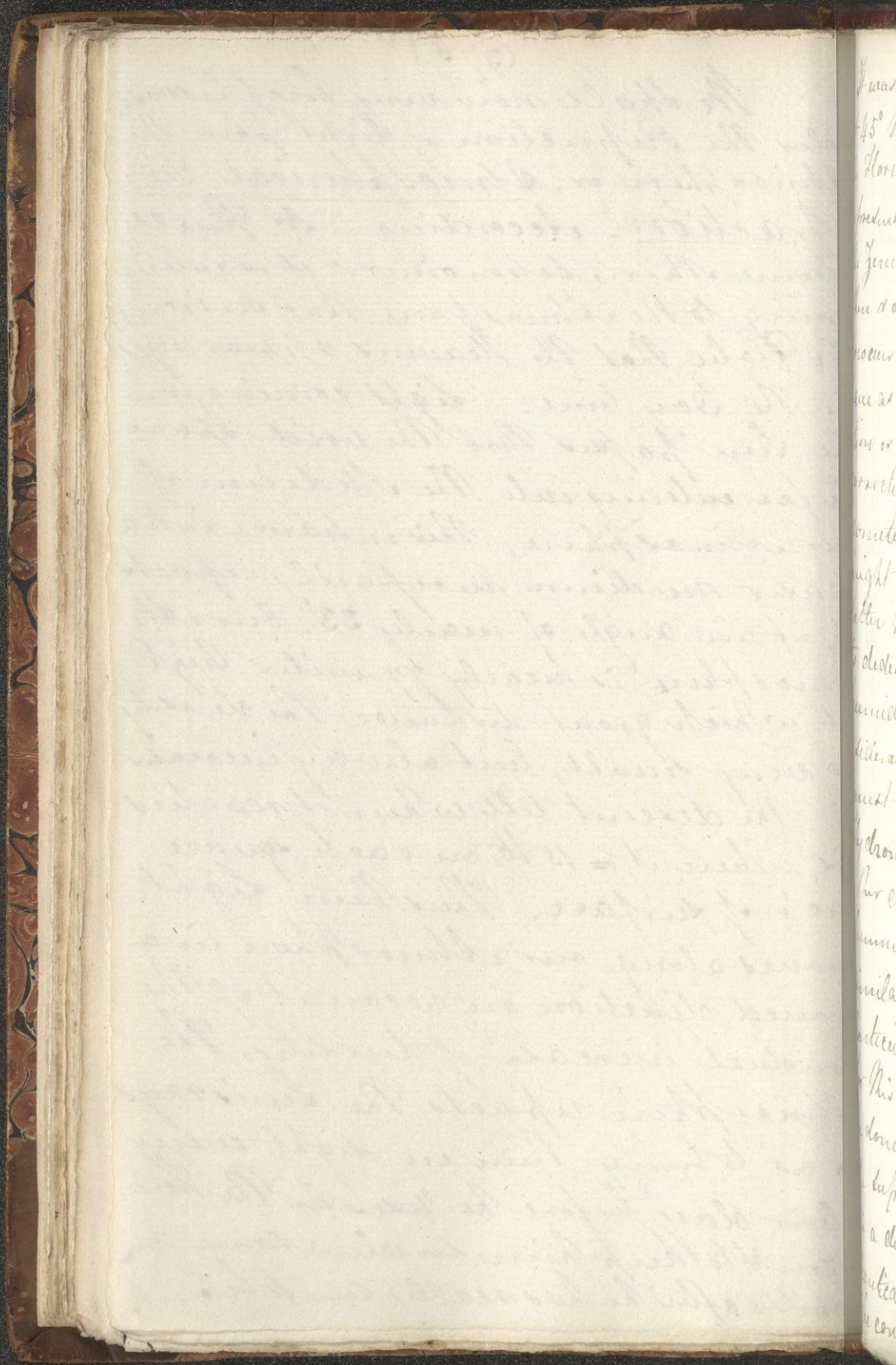
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looking steadfastly at it for some time. When remove it, we imagine we still see an object but coloured Blue, which Blue has therefore tho' improperly been termed the accidental colour of Red. Red in its turn is the accidental colour of Blue. The accidental colour of Orange is Blue with a mixture of Indigo. That of Yellow is Indigo & Violet. Of Green is Violet. That of Blue is Red. Of Indigo is Yellow & Orange. That of violet is Green with Blue.

These colours were first particularly observed by Buffon who however did not clearly explain the Cause. It may be explained thus The eye becomes fatigued & when drawn from the object on which it gazed so attentively, it supposes still that it sees not the same colour, but that ~~with~~ ^{with} which with the former compose the ground (White) on which you try this experiment. After looking earnestly at the Red & it is removed then you imagine you see the White ground minus the Red which is just Blue. This certainly gives some account of the Phenomenon but whether exactly I cannot pretend to say.

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We shall now very briefly consider the Refraction of light from the Atmosphere or Spherical Refraction. According to Dr. Keell & some other Astronomers it is entirely owing to the atmosphere that surrounds the Globe that the Heavens appear bright in the Day time. Light coming from the Sun passes thro' the void space before entering into the Medium of our Atmosphere, this entrance into a denser medium necessarily refracts it, at an angle of nearly $33'$. But the atmosphere is nearly 77 miles high at which great distance the density is very small, but always increases in the descent till when it reaches us, when it is 15 lb on each square inch of surface. Thus then light moves along our Atmosphere in a curved direction on account of the gradual increase of density. The Atmosphere refracts the Sun's rays so as to bring them in sight every clear day before he rises in the Horizon & to keep him in view some minutes after he has really sunk below it.



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It was computed by Dr Bradley that at 45° the refraction = $57''$ when seen the Horizon it = about $33'$. If then L represent the distance of the point from the Zenith, & the refraction as computed then it always equals $57'' \times \text{Tang. } L$ when however this is properly corrected we have as a general expression the Refraction or $r = 57'' \times \text{Tang. } (L - 34)$ For this correction we introduce both the Barometer & Thermometer call the height of the former b , that of the latter h then we have $\frac{b}{29.6} \times \frac{h + 350}{400}$ to deduct from the result. As the humidity also affects in no inconsiderable degree the Refraction we must also take into account the Hygrometer. At no time is the weather clearer than after rain in a Summers evening, Mistiness & other similar causes affect observations, particularly as to heights, we therefore for this acquire a correction. This may be done thus - supposing we know the supposed distance in English Miles in a direct line; reduce then this to nautical miles supposing 6000 ft to be contained in a Mile. Then $\frac{1}{4}$

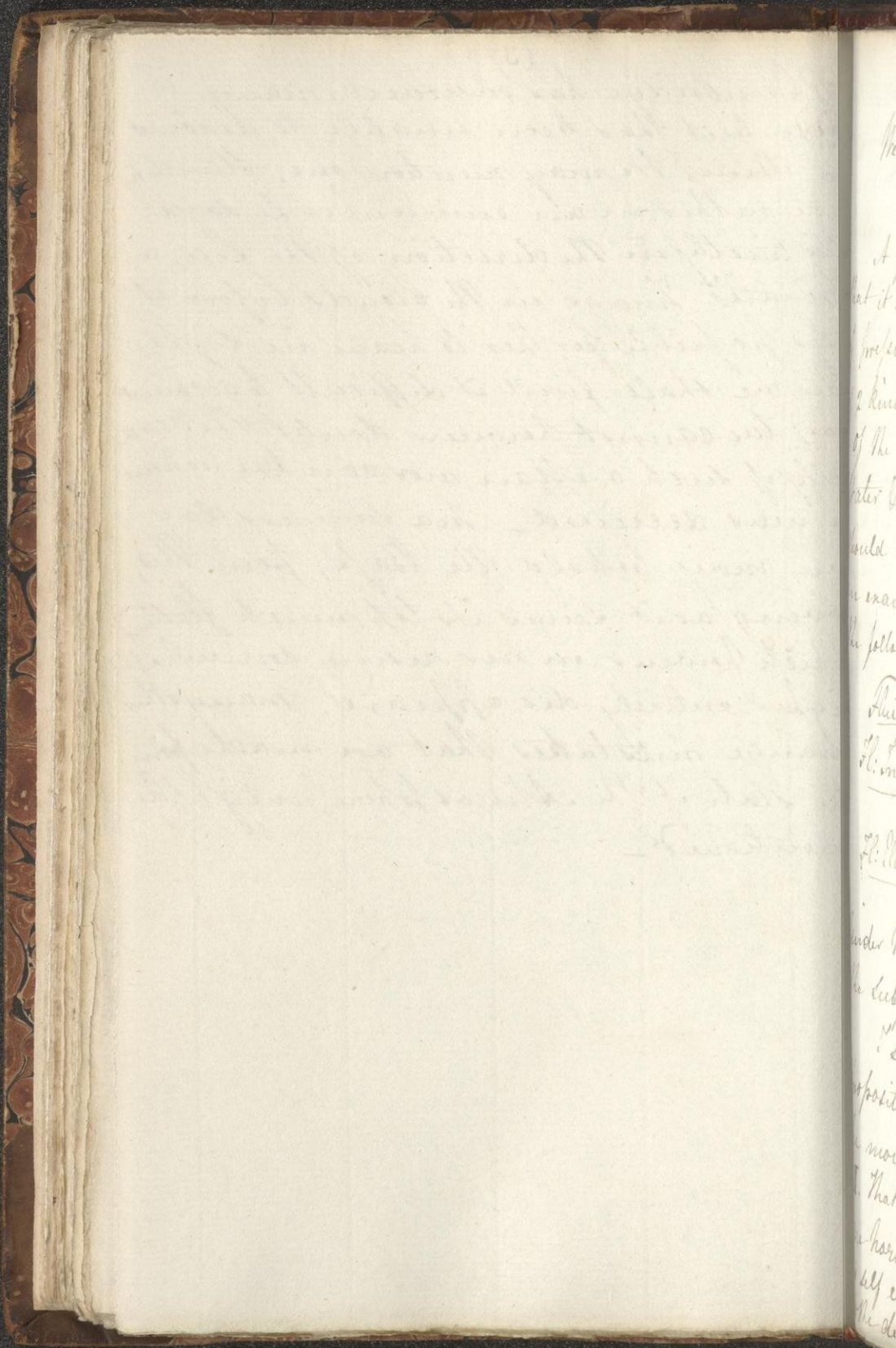
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part of the distance thus found is to be deducted from the former. Thus Ben Lomond in a direct line is about 60 nautical miles from this therefore $\frac{60}{14} = 4 \frac{2}{7}$ ft. which must be deducted from its height as found here by Trigonometry. The Atmospheric Refraction only affects the vertical position of an Object. Thus the lowest limb of the Sun from the Atmosphere suffers a Refraction of 33' that is it appears 33' higher than it really is. Now the upper limb being placed higher suffers not so considerable a refraction & therefore is not raised so high. Consequently the Sun is flattened in the upper limb. Many other strange appearances arise from this Dr Smith in his Optics mentions many & among others he relates a case of the Refraction of the Sun's beams that occurred in 1596 in Nova Zembla where after a continual Night of 3 months the Sun began to rise 17 days sooner than according to the computation deduced from the altitude of the Pole then 76° .

Mr Vince President Professor of Mathematics

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at Cambridge has observed many of these but has been unable to account for them. We may mention one, standing once rather on an eminence he saw distinctly in the direction of the Sea, a Frigate's Image in the clouds before it was possible for her to become in sight. This we shall find it difficult to account for, but we cannot however doubt the Veracity of such a Man, nor can we believe he was deceived. On a Summers day you may behold the Bax, from this, having as it seems its top much flattened which however on our rising somewhat higher entirely disappears. Many other strange mistakes that are made from the state of the Atmosphere, might be mentioned.



We shall next proceed to consider

Hydrostatics

A fluid is a Body so constituted that it will yield to the least degree of pressure however small. Fluids are of 2 kinds Incompressible & Elastic -

Of the first we have an example in Water & any other liquid, as such fluids should be called. Of the Elastic we have an example in Air or any of the Gases. The following is a table of the division -

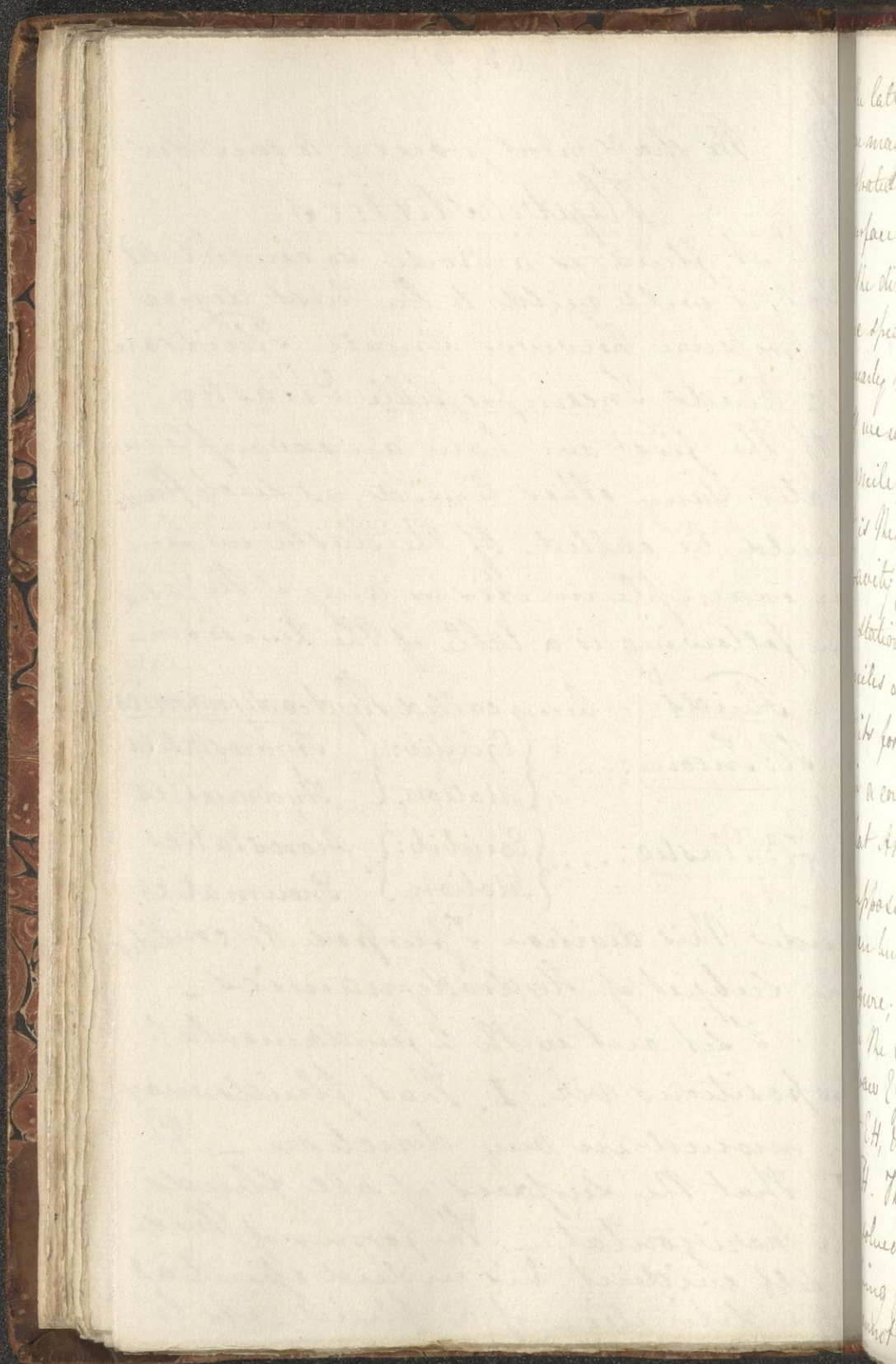
Fluids - being called Hydrodynamics

<u>Fl. Incom:</u> . . .	{ Equilib: }	= Hydrostatics
	{ Motion. }	= Hydraulics

<u>Fl. Elastic</u>	{ Equilib: }	= Aerostatics
	{ Motion. }	= Pneumatics

Under this division I purpose to consider the subject of Hydrodynamics -

I set out with 2 fundamental propositions viz. **I.** That fluids may be moved in any direction - & **II.** That the surfaces of all fluids are horizontal - The former of these is self evident & is indeed essential to the definition of a fluid - As to



The latter tho' well known to all, yet we may show how it is demonstr-
-strated. We are to show then that the
surface of every fluid is perpendicular
to the direction of its Gravity. Here we
are speaking of a very small space,
namely the surface of Water in a vessel.
If we were to include a space = to
a mile, convexity would be perceptible,
it is then = to 1'; that is, the direction of
Gravity (the Earth being a sphere) from
2 stations a mile apart = 1'; at 3600
miles or 90° it is just perpendicular
to its former direction, at 180° it is exactly
in a contrary direction. Let us suppose
that ABCD is a vessel with Water &
suppose its surface not
even but such as in this
figure; then draw EF
in the direction of Grav:
draw EG perpendicular
to EH, & LG perpendicular to EG join
FH. Then the force of EF may be re-
= solved into 2 forces, EG, GF, but GE
being perpendicular, EH the fluid
cannot be at rest. (This is demonstrated in



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many Books particularly, Cavallo's Nat. Phil.

On this is grounded the Theory of Levelling - we may on this principle easily obtain an horizontal line. for we have only to suspend a heavy body by a string & we get the direction of Gravity, a line exactly perpendicular to this is horizontal. It is well accomplished by the Spirit level, which is particularly useful in levelling Telescopes that the Horizontal angle may be taken accurately. What we call a horizontal line by this method of determining it, is not truly horizontal this being a sphere we inhabit. The allowance to be made for the curvature of the Earth is $\frac{2}{3}$ of the square of the number of miles or distance. Thus if the distance were 10 miles we must add to the object so far distant $\frac{2}{3}$ of 100 or $3\frac{1}{3}$ or 66.6 feet must be added & on account of Refraction the $\frac{1}{8}$ part of this must be deducted, so we have 57 to be added, as the True Height.

No fluid answers exactly to the definition here given of one. Still however the distinction between a fluid

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Very fine soft sand is quite desirous. A fluid always preserves the same level, tho' in different tubes of different diameters. Hence Water is conducted from Reservoirs, fountains made to spout Water &c. being all below the just level by force, & the force being removed they are made to spout up to regain their proper level.

Having proved then that fluids all tend downwards in the direction of their specific gravities, the next proposition is

III. The pressure of a fluid is exerted in every direction; so that all parts of the same fluid at the same depth press equally on each other in every direction.

In the figure before us all the parts of the fluid press equally in every direction on E.

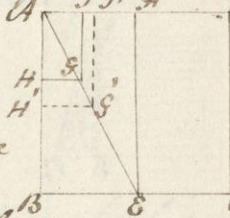
For all the parts in the pipes press equally on



each other, for if a quantity of Water be removed from any one, The surface of the Water in the whole will descend. That the pressure is equal in every direction is proved by observing that in whatever manner the tubes are connected at E, the water rises to the same level in them all.

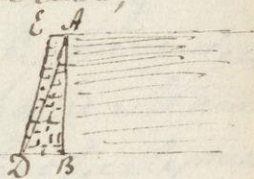
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From this then there follows an important Proposition viz "Given the vessel with the Water, to determine the degree of pressure on any point" The pressure on the bottom is just equal to the pressure of the quantity of Water that is over it. But if we wish to determine the pressure on the side this we shall find very different Suppose the point H, then draw $H'G$ parallel to the base & $G'I$ perpendicular to AF so the pressure on H is :: $AH'G'I$: $AH'G$ but as $H'G : G'I$ as $BE : EF$ therefore the pressure on the side is to the pressure on the bottom as the parallelogram $ABE'I$: ABE that is it is just $\frac{1}{2}$ the pressure on the bottom. Suppose as a numerical example that the bottom is 10 ft broad then the whole cube will be 1000 ft & suppose the pressure 62 $\frac{1}{2}$ lb to every cubic foot of Water then the whole will be 62500 lb pressing on the bottom & of course on each of the sides $\frac{1}{2}$ of it or 31250 lb $\times 4$ gives 2nd the pressure on the bottom. The total pressure then is 3 times the weight of the Water —

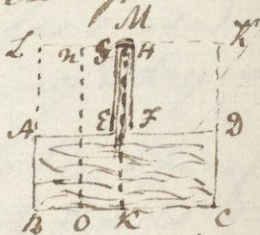


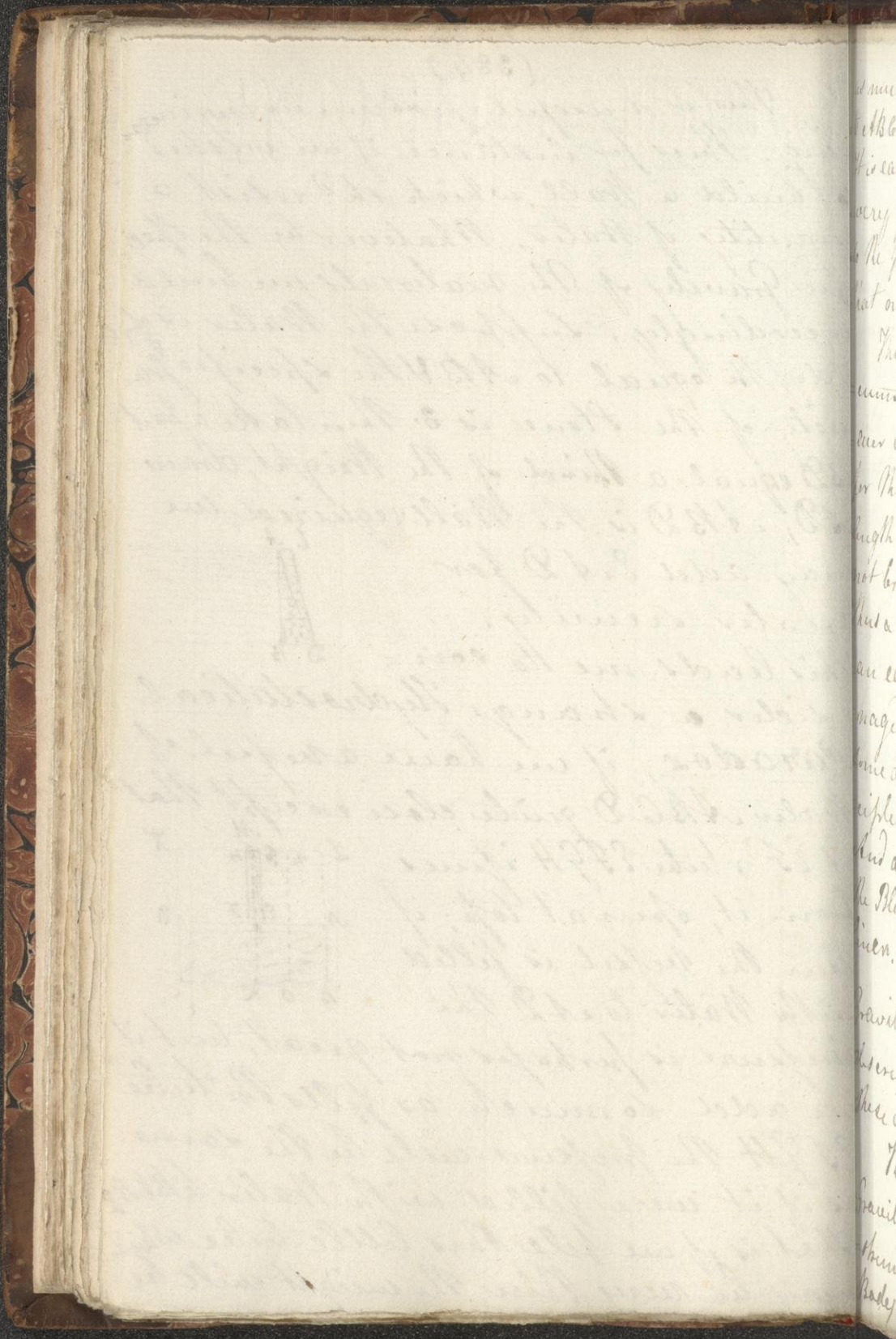
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This is a useful problem in Engineering. Thus for instance if we wished to build a Wall which sh^d. resist a quantity of Water. Whatever be the Specific Gravity of The materials we build accordingly. Suppose The Water is of a depth equal to AB & the Specific Gravity of The Stone is 3. Then take a part BD equal a third of the Height, draw AD , & ABD is The Wall required; we may add EAD for greater security.



This leads me to con- sider a strange Hydrostatical Paradox, if we have a vessel of Water ABCD quite close except that at EF a tube EFGH issues from it, open at top; if then the vessel is filled with Water to AD the pressure is perhaps not great, but if we add so much as fills the tube EFGH the pressure will be the same as if it were filled with Water to BCGE. That is if we pile this little tube which may be very thin the weight will be





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as much increased as if you had added to $ABCD$ a quantity of Water = to $ADLH$. It is easily proved for the pressure on every point is equal on all directions so the pressure on HL = ML is equal to that on O which is therefore AO .

This is a very extraordinary circumstance no mechanical force what ever can have such a power as this for this may be carried to an infinite length provided the vessel itself does not break which is the only prevention. Thus a body of Water which a Man can easily lift may if properly managed be raised by the addition of some drops of Water. It is on this principle Bramers Press is constructed. And also the various presses used in the Bleachfield for pressing & drying linen. We now proceed to the Specific

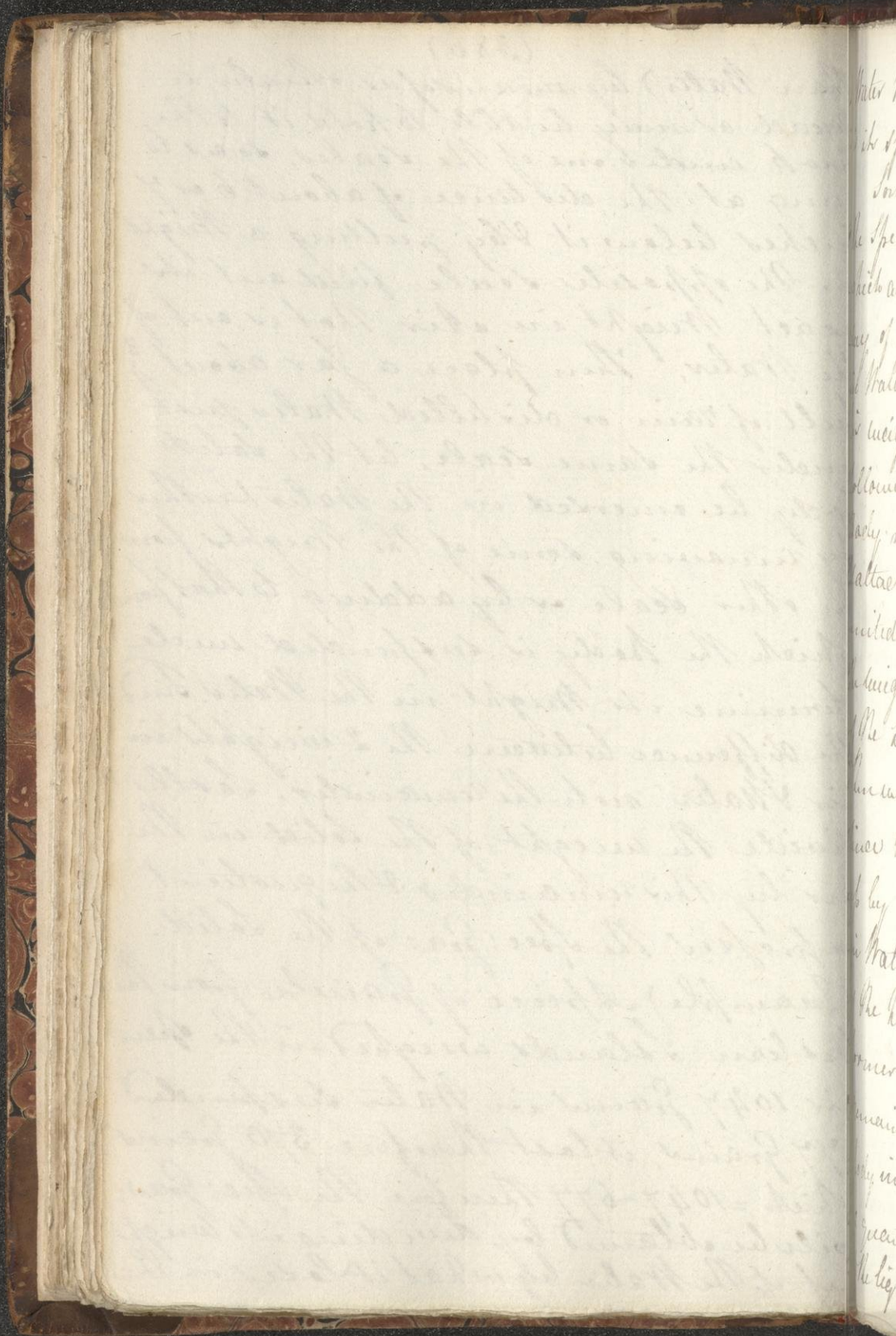
Gravities of Bodies which leads to the description of Instruments by which these are known viz Hydrostatic Balances.

The mode of finding the Specific Gravity of any Body by this useful Instrument is as follows. Suspend the Body (which we first consider as heavier

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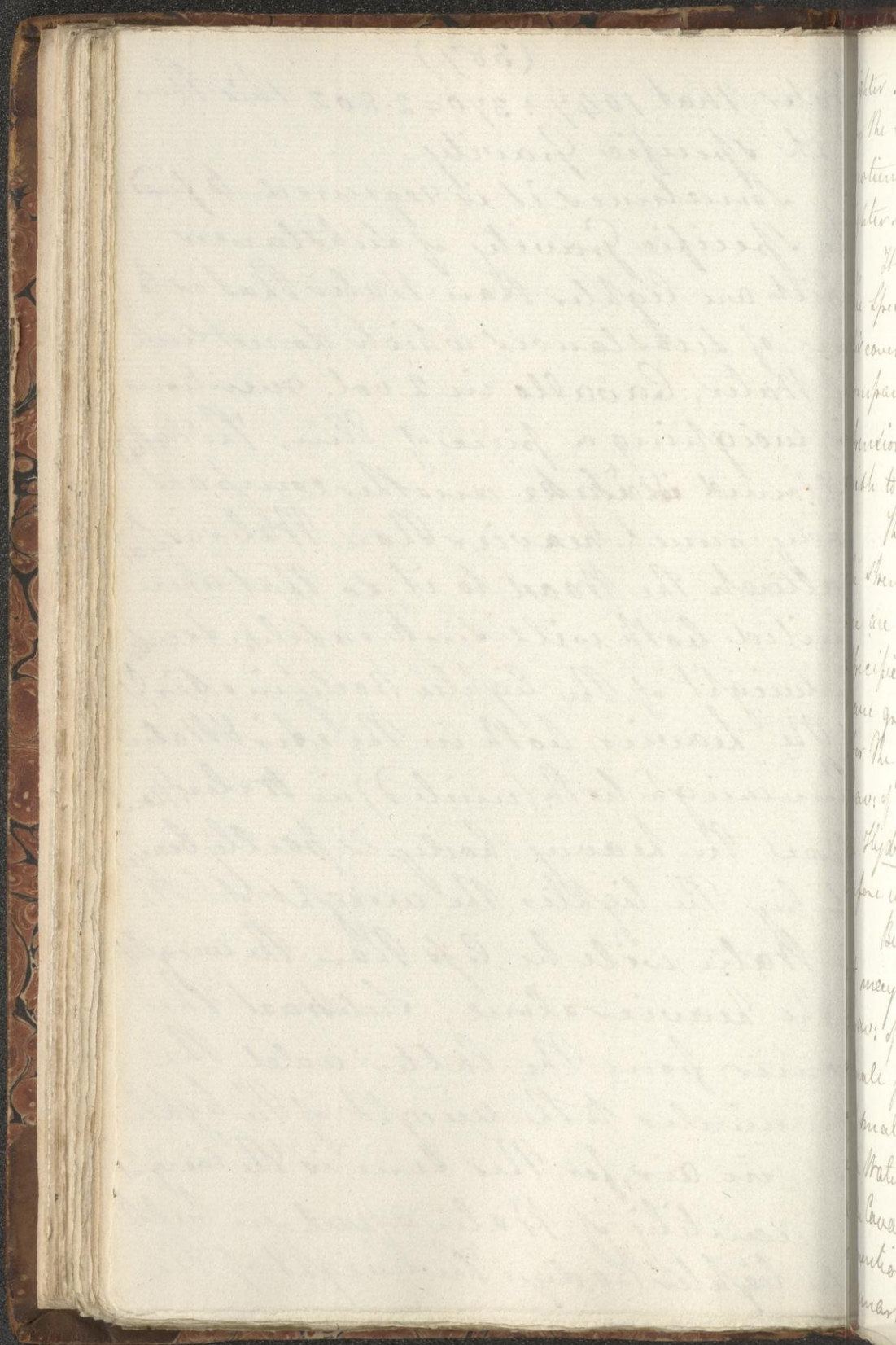
than Water) by means of as slender a thread as may be able to hold it to the hook under one of the scales, so as to hang at the distance of about 6 or 7 inches below it & by putting a Weight in the opposite scale find out its exact Weight in air that is out of the Water. Then place a Jar about $\frac{3}{4}$ full of rain or distilled Water just under the same scale, let the solid body be immersed in the Water & either by removing some of the Weights from the other scale or by adding to that part which the body is suspended we determine its Weight in the Water. Find the difference between the 2 weights in air & Water note the remainder. Lastly divide the weight of the Solid in the air by this remainder & the quotient expresses the Spec: Gra: of the Solid.

(Example) A piece of Granite from the Molten Islands weighed in the open air 1047 Grains in Water suspended 677 Grains, it lost therefore 370 Grains which = $1047 - 677$ therefore the Spec: Grav: will be obtained by dividing its weight out of the Water by what it loses in the



Water That $1047 \div 370 = 2.802$ This then is its specific Gravity.

Sometimes it is required to find the Specific Gravity of substances which are lighter than Water that is to say of substances which do not sink in Water. Cavallo in 2 vol. mentions his weighing a piece of Elm. The method followed ~~is to~~ take another compact body much heavier than Water as Lead & attach the Wood to it so that when united both will sink easily. Ascertain the weight of the lighter body in air, & of the heavier both in the air & Water. Then weigh both (united) in Water, Now since the heavy body is partly buoyed up by the lighter the weight of both in Water will be less than the weight of the heavier alone. Subtract the former from the latter and the remainder to the weight of the lighter body in air, for this sum is the weight of a quantity of Water equal in bulk to the lighter body. The weight of the



lighter Body in Air must be divided by the last mentioned sum & the quotient is the Specific Gravity of the lighter Body.

It is necessary to give an example. The Specific Gravity of Fluids are easily discovered by the same principle & comparing what a Body loses by suspension in Water & in the fluid you wish to try.

This comes to be very useful for the strength of all liquors, as spirits & wines are estimated by their relative Specific Gravity. Those which are lighter have greater strength than the heavier. For the purpose of ascertaining the Spec. Grav: of fluids an Instrument called the Hydrometer is employed, this is it before us - &c.

Besides the Bodies already mentioned it may be required to find the Spec. Grav: of other substances as that of small powder which is soluble & also of small granular substances insoluble in Water (for the solution of these problems see Cavallatool. 2. p. 56). Let me now mention the Spec. Gravity of some remarkable substances -

Platin

Gold

Alum

Lead

Silver

Cin

Zinc

Sapph

Ruby

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<u>Platina</u>	{ purified & forged	= 20.336
	{ put thro' Rollers	= 22.069
<u>Gold</u>	{ fused but not ham:	= 19.258
	{ if hammered	= 19.362
<u>Mercury</u>	{ at 32° of heat	= 13.619
	{ at 60° do	= 13.580
	{ at 212° do	= 13.375
<u>Lead</u>	{ whether ham: or not	= 11.445
	{ sometimes it is	= 11.352
<u>Silver</u>	— when hammered	= 10.511
<u>Tin</u>	— when hammered	= 7.299
<u>Zinc</u>	— simply fused	= 7.210

Mineral Bodies

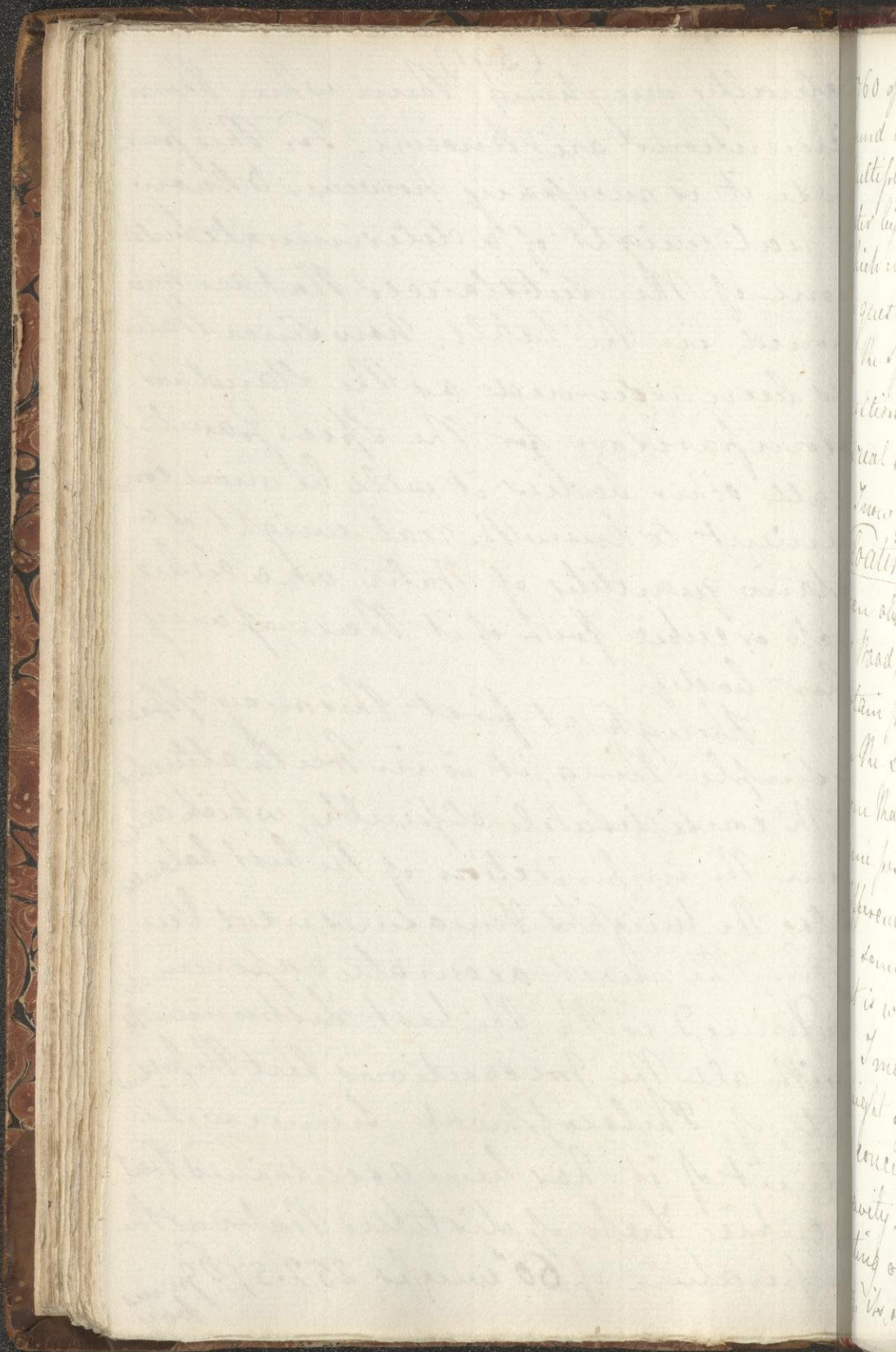
<u>Sapphire</u>	{ Oriental	= 3.991
	{ Brazil	= 3.130
<u>Ruby</u>	{ Oriental	= 4.283
	{ Brazil	= 3.531
<u>Topaz</u>	{ Oriental	= 4.011
	{ Brazil	= 3.536
	{ Saxon	= 3.564

Complete tables of Specific Gravities
may be found in many Books.
Besides showing the comparative
Gravities of Bodies which are to be seen
by bare inspection the great use of
a table of Spec. Grav. is to ascertain the
real weights of bodies & that without

[illegible]

actually weighing them when their dimensions are known. For this purpose it is necessary however to know the real weight of a determinate bulk of one of the substances that are mentioned in the table. Now since Water has been assumed as the Standard of comparison for the Spec. Gravities of all other bodies it will be more convenient to know the real weight of a certain quantity of Water viz a cubic inch or cubic foot of it than of any other body.

Though at first this may appear a simple thing, it is in truth attended with considerable difficulty, which arises from the imperfections of the best balances & also the weights & measures used. Even from the most accurate experiments performed with the best Instruments & with all the precautions that the present state of Philosophical Science will admit of it has been ascertained that a cubic Inch of distilled Water at the temperature of 60° weighs 252.576 grains
 Troy

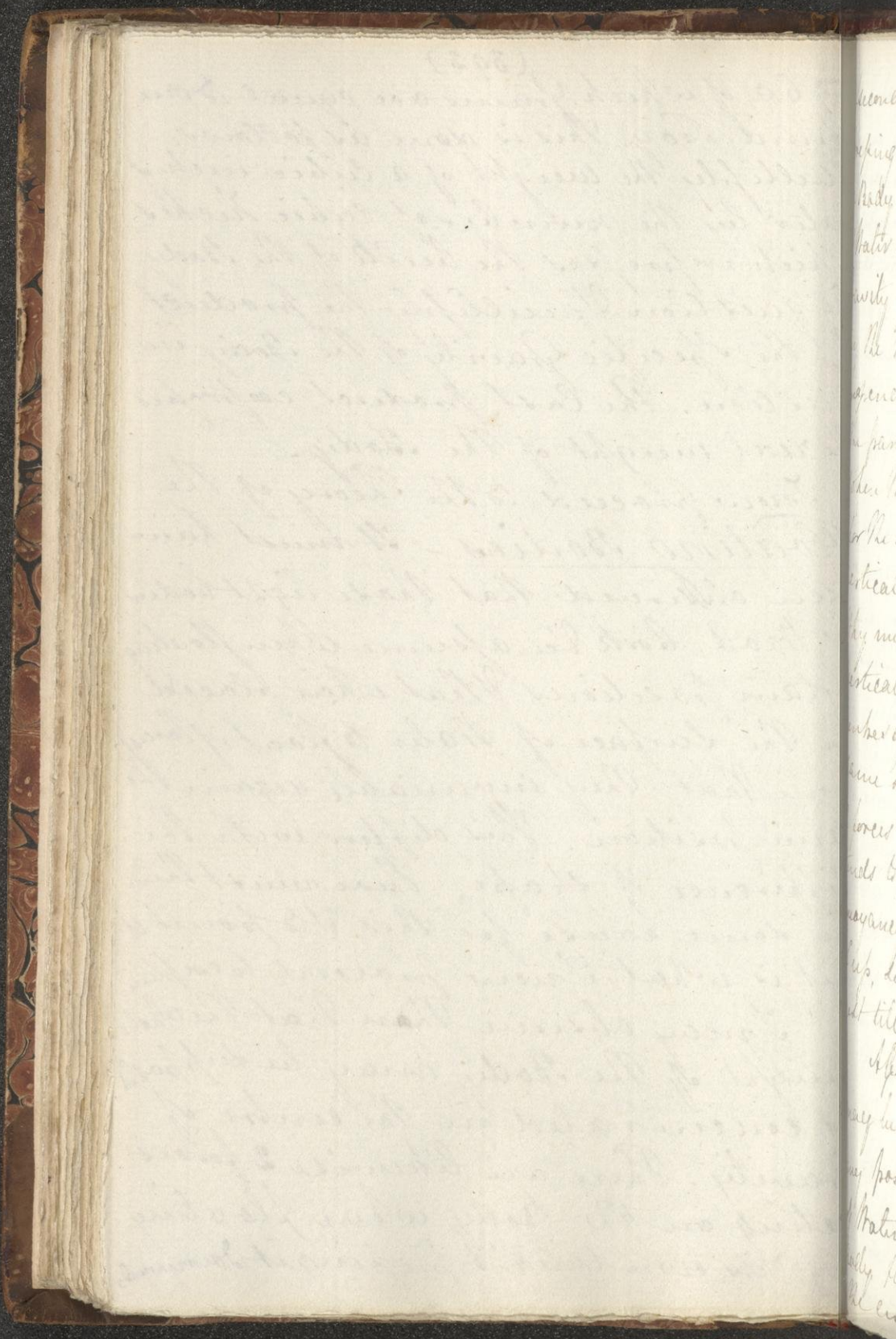


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5760 of which Grains are equal to one pound Troy. This is done as follows. Multiply the weight of a Cubic inch of Water by the number of Cubic Inches which expresses the bulk of the Body in question. Multiply the product by the Specific Gravity of the Body in question. The last product expresses the real weight of the Body.

Now proceed to the Theory of the Floating Bodies - It must have been observed that those light bodies as Wood, Cork &c assume when floating certain positions that when placed on the Surface of Water to float if thrust from that, They invariably regain the same position. This differs with the difference of shape. There must then be some cause for this. I now proceed to explain.

I may observe then that the whole weight of the Body may be supposed as concentrated in the centre of Gravity. There are likewise 2 forces acting on the Body when floating viz. Its own weight pressing it downwards,



Secondly the buoyancy of the Water
 pressing it upwards. So that suppose
 a Body $EFGH$ to be floating on a surface
 of Water ABD . The centre of Gravity of the part immersed



in the Water sh^d be exactly perpendicular to the centre of Gravity of the part which is above the surface. When the body $EFGH$ will float easily for the 2 centres of Gravity are in one vertical line Kd . It may be asked Why must they be in the same vertical line? Then suppose the 2 centres of Gravity are at K & d not in the same straight line. Then there are 2 forces acting on this one M K which tends to pull down K another Kd (the buoyancy of the Water) tending to draw d up, so the line Kd cannot be out but till Kd turn into a vertical line.

A body that is perfectly spherical may be made to float in Water in any position. Suppose $ABCD$ the surface of Water & that EFG is a spherical body floating in the surface; then the centres of Gravity of the immersed

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part of the part above the surface must both lie in the vertical diameter. It so that in whatever position it is placed it will retain that position.



"On the Stability of Floating Bodies" you will find an excellent paper in the Philosophical Transactions for 1796. The Life Boat is built on these principles; a sheeting of Cork is placed over the Wood reaching within $\frac{1}{2}$ foot of the surface of the Water so that on being much pressed to either side, she more easily supports the pressure, & instantly rights on it being removed. To promote the stability of Floating Bodies on Water the centre of Gravity of the part above sh^d be kept as low as possible.

A Ship (Le Hannibal) built at Brest according to the strict rules of Theory, was launched & to the surprise of the Spectators was found not well balanced. After being examined by all the Theoretical & Practical Men in the Country she still remained extremely ill set on the Water. A considerable Carpenter working in the Dock Yard at Brest

capit

proposed that a sheeting of light wood
 shd be put round keel-ticks, & this being
 done she was instantly all right. This
 shows how practice sometimes differs
 from the strict Theory. On this interesting
 subject of Ship building a subject
 much better understood in France
 than with us, much has been written.
 Bouguer has a very good treatise on
 it, which may be found translated
 by Mr Henry Watton. The famous
 Euler has also written an excellent
 treatise on this curious Art. As also
 Mr Atwood our own Countryman.

I now proceed to consider
Capillary Tubes. Then we are to
 consider Capillary Attraction. That
 is the Attraction by which water is raised
 in very small capillary Tubes, & thus
 showing an Attraction as it appears
 between the Water & Glass. These Capil-
 lary tubes are sometimes of amazing
 fineness being at times not greater in
 diameter (that is the bore of the tube)
 than 100 part of an Inch. In such a
 bore the utmost height water can rise
 is 5 inches; the 2 multiplied together

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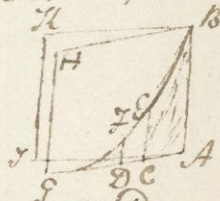
producing .053. This is always the case
 were there $\frac{1}{10}$ of an Inch & would rise
 to the height of $\frac{1}{2}$ an inch or .5 of an
 inch, for $.5 \times \frac{1}{10} = .053$ etc

Not almost all fluids rise in
 small tubes, & constantly when a little
 wet, yet there is one remarkable excep-
 tion Mercury. This substance instead
 of rising sinks that is its
 edges do not rise as those
 of Water but fall, as seen
 represented here.



It is a very curious observation
 one that is completely proved by Theory
 that if a drop of Water be introduced between
 2 glass plates united at one end, then on
 gradually closing these plates the
 Water is pressed & forms a distinct
 Hyperbola. This easily proved as follows:

Suppose the 2 plates are
 A B G H, & A B I K. The Al-
 titudes of the Water here
 at different distances from C D are
 inversely as the distances between
 the two plates at those places (Cavallo
 III p. 130) Therefore $CE : DF :: AD : AB$
 and therefore $CE \times AB = DF \times AD$ which
 is just



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The principal property of the Hyperbola
 of Capillary Attraction there is
 as yet little certain knowledge, various
 Theories have been framed to account
 for the Phenomena but no one has yet
 appeared which has received the sanction
 of all. Much as La Place has been re-
 -spected for his Theory I cannot help
 thinking that it is the best explanation
 yet given of this difficult Subject. (See
 Cavallo 3^d. 140.) In the Philosophical
 Transactions published more than 50
 years ago a paper on this subject may
 be found written by Dr Jurin.

We now proceed to the second di-
 -vision of incompressible Fluids; we
 have considered them at rest under
 Hydrostatics, we shall now consider
 them in Motion under -

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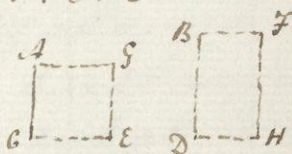
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Hydraulics

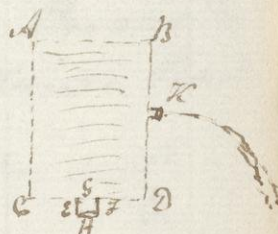
To fluids bodies in rest we apply with utmost facility Mathematical demonstration. Here however, tho' this demonstration may be applied yet not with the same facility. Therefore it will comprehend much attention to understand this subject. The first proposition is. 1. "Two Bodies acquire equal velocities at the end, if they have been accelerated over an equal space in an equal portion of time" Thus suppose there are 2 Parallelograms $ACGE$ & $BDHF$. If $AC : BD :: BF : AE$ then

$$2 AE \times AC = 2 BD \times BF$$

for $2/x = v^2$, $2 AE \times AC = v^2$ & $2 BD \times BF = v^2$. Thus

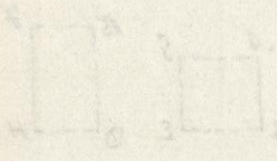


suppose there is a vessel full of Water. Suppose there is a small orifice at EF & the stream be represented by GH .



$AC : GH ::$ The pressure of the superincumbent Water : The velocity with which it issues out that is to say $P : q :: AC : GH$. If the Water be supposed to flow out at H

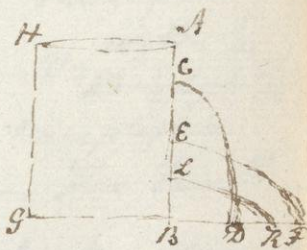
The first part of the book is devoted to a general
description of the various species of the genus
which have been hitherto described. The author
then proceeds to describe the new species which
he has discovered. The description of each species
is given in a separate section, and is accompanied
by a figure of the animal. The figures are all
drawn by the author, and are of a very high
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it then forms a Parabola of which the directrix is AB . This is the Theory, but when put to practice from various external causes it is far from being an accurate Parabola. Just as in the case of Projectiles already considered. If then we suppose h the height of the fluid, g the space in which it falls in 1st (32 feet) we have the velocity with which it will run out $v = \sqrt{2gh}$ for $2gh = v^2$ so as $\sqrt{2g} = \sqrt{64}$ or 8, v becomes equal to $8\sqrt{h}$. If a^2 be the area of the vessel & quantity of Water flowing in a second. Then $q = a^2 \sqrt{2gh}$ or $q = \frac{5a^2}{7} \sqrt{2gh}$, a minute deduction may yet be made. If we have a vessel $ABGH$ full of Water & if at any point such as L we make a small orifice then the Water rushing out at this small orifice will form a Parabola. It is a curious circumstance that if 2 orifices be made above this, the middle one will a Parabola of the greatest horizontal range, if it may so express it. If we make



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a^2 The area of the vessel, h The height of water in it, & the velocity of any falling Body per second g : g = quantity of Water that flows out when will $g = a^2 \sqrt{2gh}$: but $g = 32$. therefore $2g = 64$ & $\sqrt{2g} = 8$ consequently $g = 8a^2 \sqrt{h}$.

Whether Water runs thro' Pipes or as rivers it is naturally accelerated by its own Gravity. The time that a cylindric vessel (The area of its base being b^2) requires to empty itself by a hole at the bottom of which the area is a^2 the depth at the beginning of this discharge being d is $\frac{b^2}{a^2} \sqrt{\frac{2d}{g}}$ the time that the surface takes to sink from the depth d to any other depth $d' = \frac{b^2}{a^2} \left(\frac{\sqrt{d} - \sqrt{d'}}{\sqrt{\frac{1}{2}g}} \right)$. On this principle depends the construction of the Pleydra or Water-clock.

(Art. 291) see Note here.

(Art. 292) The Velocity therefore being supposed uniform $V = \frac{307 \sqrt{R} - \frac{1}{10}}{S^{\frac{1}{2}} - \frac{1}{2} \log(S + \frac{16}{10})} - \frac{3}{10} \sqrt{R} - \frac{1}{10}$ or it may be thus simplified $V = \sqrt{R} - \frac{1}{10} \left(S^{\frac{1}{2}} - \frac{307}{\frac{1}{2} \log(S + \frac{16}{10})} - \frac{3}{10} \right)$. For this I refer you to the authors (See the author's Book where the French may also be found).

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reduced to English. When R & S are very Great Then V becomes nearly = $R^{\frac{1}{2}} (S^{\frac{1}{2}} - \frac{1}{2} \log. S - \frac{3}{10})$ The Logarithms here understood are Hyperbolic. The slope remaining the same the velocities are as $\sqrt{R - \frac{1}{10}}$. The velocities of 2 great Rivers that have by no means the same declivity are as the square roots of the Radii of their sections. If R be so small that $\sqrt{R - \frac{1}{10}}$ or $R - \frac{1}{10}$ the velocity will be nothing; which is agreeable to experience for in a cylindrical tube $R = \frac{1}{2}$ the Radius, the Radius therefore equal $\frac{1}{10}$, so that the tube is nearly capillary & the fluid will not flow thro' it. The velocity also = 0 when the declivity is so small as $S^{\frac{1}{2}} - \frac{1}{2} \log. (S + \frac{16}{10}) - \frac{3}{10} = 0$

Suppose it were required to carry Water from one place to another the declivity being equal to 1 foot in a mile then from what has been mentioned the formula for this will be

$$V = \sqrt{R - \frac{1}{10}} \times (S^{\frac{1}{2}} - \frac{1}{2} \log. (S + \frac{16}{10}) - \frac{3}{10}) \text{ now as}$$

$$R = \frac{r}{2} \text{ \& } S = 5280. \text{ this expression becomes}$$

$\frac{9}{10} - \frac{1}{10} = \frac{8}{10}$

$v = \sqrt{24 \left(\sqrt{5280} - \frac{307}{2} \log. 5280 - 528 \right)}$ This then
 is the proper expression for the velocity
 per second. The velocity of the stream
 is different in different parts on or
 towards the surface it is more rapid
 than at the bottom or middle, by
 very careful observations & laborious
 experiments Mons.

has at
 length discovered a formula which
 expresses the Mean velocity of a stream
 of Water. His usual method was al-
 lowing a light Body to float down
 the stream on the surface & by much
 sinking it somewhat heavier allowed
 it to go down again. By putting it
 still deeper & observing with much
 accuracy its velocity over a certain
 space he at length obtained the formula
 as follows "If from the square root of
 the velocity of the middle of the stream
 unity be taken, then the remainder
 squared expresses the bottom velocity.
 The expression is v the bottom velocity
 $= \sqrt{v-1}^2$ from this we easily determine
 the velocity at the bottom which
 must be $v - 2\sqrt{v+1}$ Therefore that at
 the top $2v - 2\sqrt{v+1}$. Take then the $\frac{1}{2}$

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of this line have the mean velocity =
 $v - \sqrt{v} + \frac{1}{2}$. Suppose the velocity were
 nearly 4 feet in a second or say 49
 inches & the formula is $49 - \sqrt{49} + \frac{1}{2} =$
 $49 - 7 + \frac{1}{2} = 42\frac{1}{2}$ mean velocity; The
 velocity at the bottom will be $49 - \frac{1}{4} + \frac{1}{2} =$
 36 inches per second; at the top $98 - \frac{1}{4} + \frac{1}{2} =$
 85 inches. Hydraulics have been
 much indebted to this same author
 for his many assiduous observations.
 It is a curious circumstance that
 2 Rivers after uniting do not appear
 much larger than one of them was
 before their union. When they unite
 there are 3 different alterations which
 may occur, it may be widened, it
 may be rendered deeper, & its velocity
 may be increased. The first of these
 seldom occurs, the second frequently
 does, but the latter almost always.
 Suppose then there is a River 10 ft
 wide & 1 ft deep, another river of the
 same dimensions uniting the depth
 is increased to 1.48 & the velocity will
 be somewhat increased nearly as 37:50.

The subject of Running Rivers we
 shall at present fortake as it will

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afterwards be renewed when we come to treat of the ethereal sphere &c. We shall next direct our consideration to the

Sec. 3. Percussion & Resistance of Fluids

Art. 297. Now keeping in mind that the forces are as the squares of the velocities if we call a^2 the action of a stream, & the velocity, & the force of the stream, m = a given quantity of water then we have $f = m \times a^2$ or $f = m a^2 \times 2gh$ i.e. the force is as the square of the velocity. The effect (E) of the machine depends on the velocity of the stream, & the weight of the waterfall (W) that is $E = W \times v = m a^2 v^3$ or the effect = the height of the $W \times$ into its own square root. But it may happen that we are not estimating the force of one stream, but comparing together the force of two, in which the ~~expenditure~~ ^{expenditure} is the same, but the velocities very different. Now we know that in the one $v = m a^2 v^3$ but in both $a^2 \times v^3$ is the same = c or $a^2 \times \frac{v^3}{c}$ therefore $E = m \cdot c \cdot v^2$. When the expenditure and velocity are the same then the forces or effects of the stream are as the cubes

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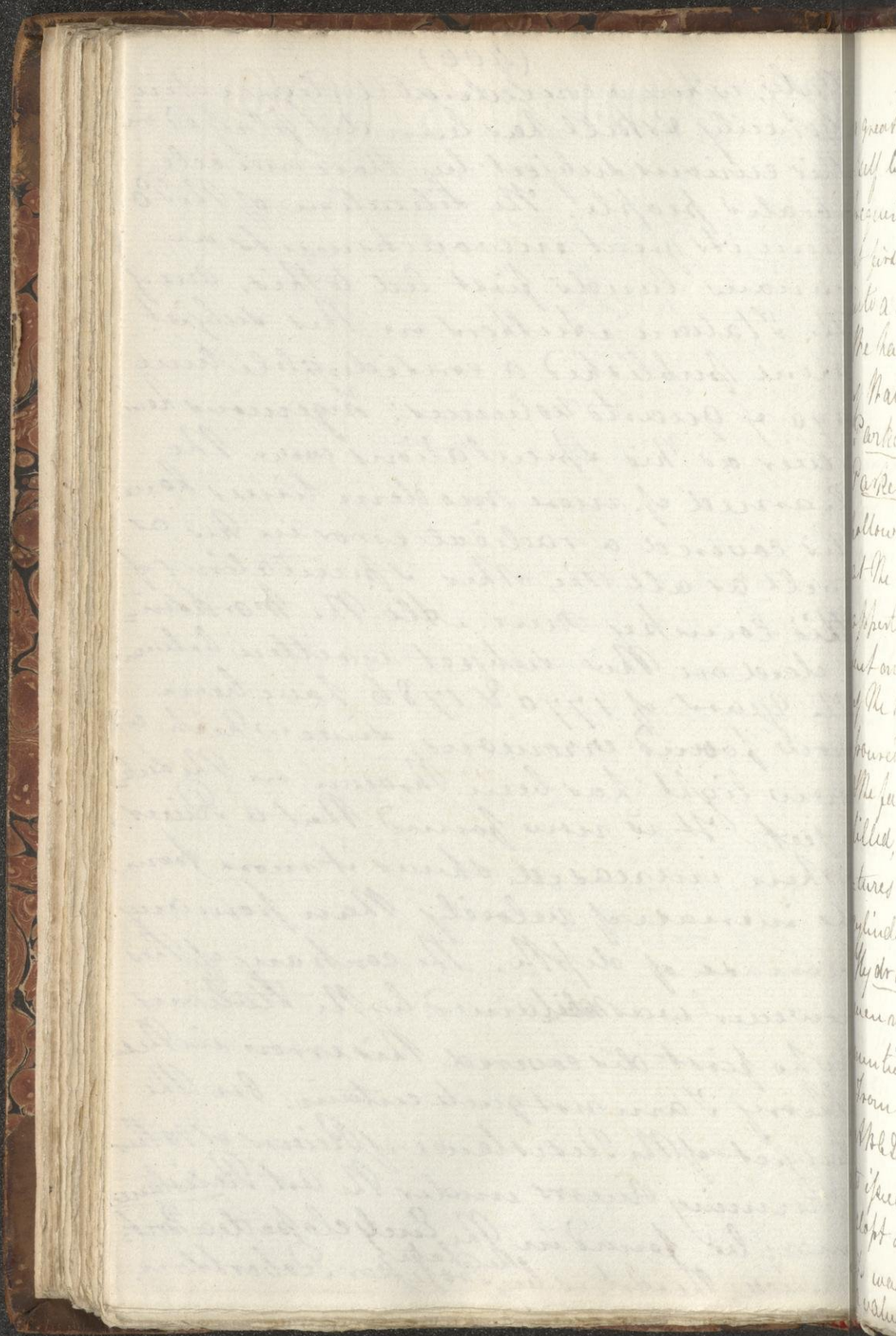
of the velocities. If the expenditure be the same, but the velocities different then they are as the squares of the velocities.

Let's Machines worked by Water are of 3 different kinds. They may be looked 1. by Impulse, 2. The Weight, & 3. The Reaction of the Water. Those which are by Impulse are few in variety. They are much used being simple in the construction & easily managed. They depend for their effect on the Height & Length of the fall. This is the common Overshot Wheel in which the motion is produced by the Waterfall filling the boxes which surround as it were the exterior of the circumference - (at 30%) Those machines worked by the Weight of Water are simple enough but not so commonly employed as the former. Instead of having the interior circumference composed as it were by a series of buckets, it has a series of flat boards on which the Weight of the Water pressing forces the Wheel round; this requires more Water than the former. "Running Rivers"

The subject of "Running Rivers" has long been much attended to in

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Italy, where a considerable degree of ingenuity & skill has been displayed on this curious subject by those once celebrated people. The situation of the Po from its great encroachments on various lands first led to this. One of the Italian authors on this subject alone published a considerable time ago 7 quarto volumes! Ingenious however as his speculations were the learned of more modern times have discovered a radical error in his as well as all the other speculations of his countrymen. All the works decided on this subject written between the years of 1770 & 1786 have been now found erroneous, since which a new light has been thrown on the subject. It is now found that a River when increased shows it more from the increase of velocity than from any increase of depth. The contrary of this however was ~~maintained~~ by the Italians who first discovered this error in their theory I am not quite certain. On the subject of the Resistance of Rivers or rather of Running Rivers under the Art. Resistance may be found in the Encyclopedie Brit. tanica, the Art. is by ^{the late} Professor Robertson.



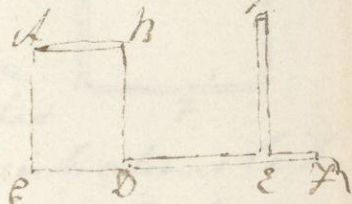
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Water most frequently when in a great mass forms a declivity for itself by its regurgitation, that is it frequently by various causes runs at first deep till at length it strikes into a declivity. We come very rapidly to the Reaction (Art 311) of Water 2 kinds of Machines. viz Parker's Mill & the Hydraulic Ram. Parker's Mill. This consists first of a hollow tube AB with an inclined box at the bottom $CB D$. This box has an aperture at each end, but on different sides of the box. The Water is poured in at the top at the fall of Water being great & the box filled, the Water rushes out at the apertures & by its reaction turns round the cylinder AB .



The Hydraulic Ram is an invention more ingenious. I shall only mention the principle.

From a vessel of Water $ABCD$ a tube is supposed to issue & if suddenly stoppt at F will make



the way thro' E up the tube, which has a valve at E . The Water thus is raised in the tube.

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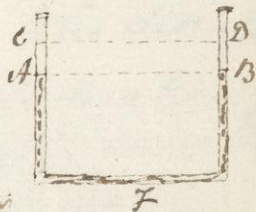
(Sec. 4) Motion of Waves

These are just the undulations of Water, indeed a species of vibration. Suppose at B & D the level of the Water is unequal, when in waves

it presents a different aspect. These parts are successively raised & the Water tho' continually falling & rising thus never moves forward, it is not by the Waves that Water is carried forward. (A. 1302)

you may exemplify this in some degree by the undulations of a glass tube such as this where allowing the Water to rise in one limb & then taking off the finger the undulations which follow will continue both legs acquire the same level. To demonstrate this on Mathematical principles. Suppose there is a bent tube AFB.

If the Water be higher in the one leg than in the other then allow them to vibrate till the Water is level in both. The vibrations like



those of a Pendulum wd be frequently isochronous were it not for some external causes. Now to the time of a

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vibration $= n\sqrt{\frac{L}{g}}$ or $t = n\sqrt{\frac{a+b}{2g}}$ now the square root of $2g$ is just the $\sqrt{64}$ or $= 8$ so $t = \frac{n}{8}\sqrt{a+b}$ or otherwise expressed we say $t = \frac{n}{8}(a+b)^{\frac{1}{2}}$. In Sir Isaac Newton's work the α which is very small is always neglected & $t = \frac{n}{8}\sqrt{b}$. The velocity of the waves is therefore as $\frac{1}{t}$ or as $\sqrt{b}$. This however is merely an approximation.

The waves being agitated beneath the surface by hidden rocks &c. is the cause of Breakers. Surf is occasioned by a heavy sea rolling impetuously over a sand bank or against a slope. In some parts of the Torrid zone the surfs which are produced on the shores are very different from any in the Temperate zone. They are very violent & sometimes occasion the loss of ships. This however is connected with the subject of the Trade Winds afterwards to be discussed. I shall finish the consideration of incompressible fluids with some remarks on the nature of Water.

Water was as long considered as an elementary substance. Till the great discovery of Cavendish that it is a compound body composed of

(1800)
The first part of the book is devoted to a description of the
various roots of the plant, and the manner in which they
are used in the preparation of the various medicines.
The second part is devoted to a description of the
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The third part is devoted to a description of the
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Oxygen & Hydrogen. This fact is now admitted by all, but since Hydrogen alone at the negative extremity of a Galv. Bat. produces Water, Oxygen alone at the other, so that by one & the same means it is produced, some have been inclined to rank it still as an Elementary. By Cold it is converted into a Solid Mass, by heat into an Elastic Fluid. There is a certain proportion of these ingredients which compose Water, & this proportion alone, produces it, sometimes by passing an Electric Spark thro' the Galv. Bat.

I next proceed to the consideration of Air under its various properties, when in Motion as in Wind &c it forms the Science of Pneumatics but when at rest the subject of Acoustics.

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Aerostatics -

Previous however to considering the particular properties of air, I have thought it proper to give you a very brief detail of the interesting subject of Caloric or Heat. Art. 313.

Caloric is extended over all Nature, & has no dependance whatever on any other body for its action. Heat of course cannot exist unless imbedded in some thing. There can be no heat without something heated, just as there can be no thought without a sentient being. It differs much in the degree in which it exists in various bodies. Art. 314. The Thermometer measures the degree of heat. Fahrenheit when he first formed this instrument, the greatest cold he could produce was by a mixture of Snow & Salt this he called zero or 0 in his scale, according to this he found that at 32° above 0 water froze this then he called the "freezing point" at 212° above 0 he found water boiled, this then he called the "boiling point." All bodies whatever both solid & fluid are subject to the same power of heat but not in the same degree. Gold for

Journal for 1862

The weather was very warm and sunny. We went for a walk in the park. The children were very happy. We saw many beautiful flowers. The children played for hours. We had a picnic under a big tree. The food was very good. We all enjoyed it very much. The day was very pleasant. We went home in the evening. The children were tired but happy. We had a good night's sleep. The next day was also very warm. We went to the beach. The children played in the sand. We saw many seagulls. The water was very blue. We had a picnic on the beach. The food was very good. We all enjoyed it very much. The day was very pleasant. We went home in the evening. The children were tired but happy. We had a good night's sleep.

Journal for 1862
The weather was very warm and sunny. We went for a walk in the park. The children were very happy. We saw many beautiful flowers. The children played for hours. We had a picnic under a big tree. The food was very good. We all enjoyed it very much. The day was very pleasant. We went home in the evening. The children were tired but happy. We had a good night's sleep. The next day was also very warm. We went to the beach. The children played in the sand. We saw many seagulls. The water was very blue. We had a picnic on the beach. The food was very good. We all enjoyed it very much. The day was very pleasant. We went home in the evening. The children were tired but happy. We had a good night's sleep.

instance may be exposed in a furnace
 It cannot be fused but may be
 so much enlarged in its bulk. If we
 suppose Gold when first put into the
 Furnace = 1. but when much heated en-
 larged in bulk to 1.0014. If we call
 $.0014 = x$ then $1+x$ is the bulk after being
 taken out now $(1+x)^3 = 1 + 3x + 3x^2 + x^3$ but
 as $3x^2 + x^3$ make little difference in the
 increase they may be omitted therefore
 $1+3x =$ the extension of the solid. The
 mode adopted by Mr Wedgwood
 (Art 316) for measuring the degrees
 of temperature is ~~very~~ ingenious;
 it is by means of particular clay
 shapes which by heat contract, this
 contraction is measured by a metallic
 scale on these being removed from
 the furnace &c

(Art 318) The general expression is
 $\Delta = D(1 - \frac{1}{n})^t$ which in the solution is
 much simplified by logarithms
 $\log \Delta = \log D + \log (1 - \frac{1}{n})^t$ or more simply
 $\log \Delta = \log D + t \log (1 - \frac{1}{n})$
 (Art 322) may be thus exemplified,
 call M & t the quantity of Water &
 its temperature, & their temperature
 after being mixed then we have

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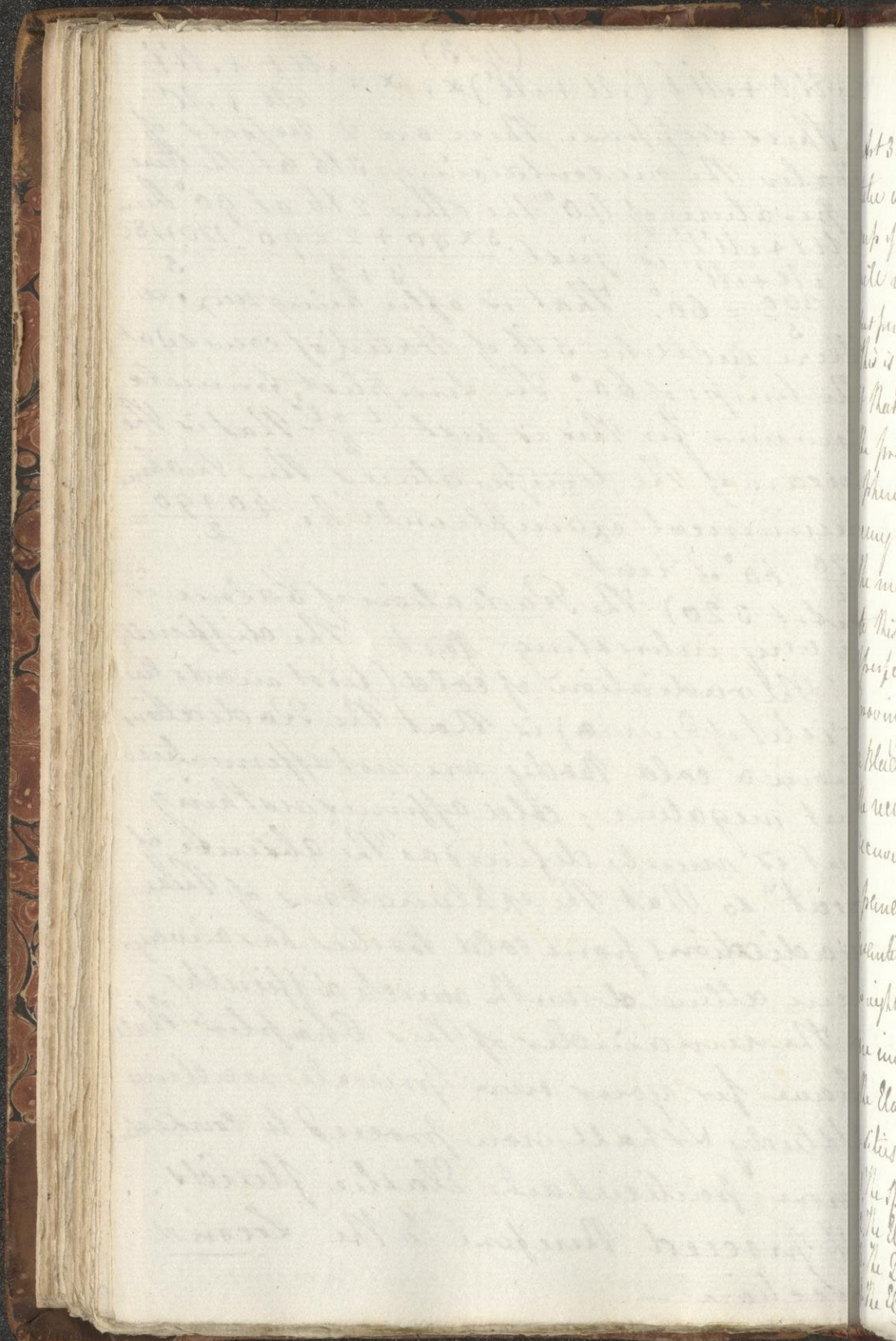
(4/3)

$$Mt + Mt' (M + M')x; x = \frac{Mt + Mt'}{M + M'}$$

Thus suppose. There are 2 vessels of Water the one containing 3 lb at the temperature of 40° the other 2 lb at 90° then $Mt + Mt'$ is just $\frac{3 \times 40 + 2 \times 90}{3 + 2} = \frac{120 + 180}{5} = \frac{300}{5} = 60^\circ$. That is after being mixed there will be 5 lb of Water (of course) at the temp: of 60° . The simplest formula however for this is just $\frac{t + t'}{2}$ That is the mean of the temperatures. Thus the above numerical example will be $\frac{40 + 90}{2} = \frac{120}{2} = 60^\circ$ of heat.

(Art 320) The Radiation of Caloric is a very interesting fact. The difficulty of the radiation of cold (first made by Pictet of Geneva) is that the Radiations from a cold body are not affirmative but negative; cold affirms nothing but is merely defined as "the absence of heat" so that the explanations of these radiations from cold bodies has always been attended with much difficulty.

The remainder of this Chapter shall leave for your own private reading & study & shall now proceed to consider more particularly Elastic fluids. I proceed therefore to the Second section —



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Equilibrium of Elastic Fluids

(Art 337) If we fill completely a glass tube with Mercury, & invert it in a cup of Mercury, the Mercury in the tube will not fall altogether, but will remain suspended at a height of about 30 inches. This is just a Barometer, what then is it that suspends this Mercury? it is the pressure or weight of the atmosphere Air on the surface of the Mercury in the Cup. In addition to the many proofs adduced in the notes to this art. I may mention a very neat & perfectly satisfactory experiment for proving the Elasticity of the Air; introduce a bladder nearly emptied of its air into the receiver of an Air pump, exhaust the receiver & the bladder will become expanded, from the extension of the small quantity of air within, the surrounding weight being removed. Now the densities are inversely, as those spaces therefore the Elasticities are directly as the densities. Thus we obtain 4 proportions.

1. The spaces are inversely as the Weights
2. The Elasticities are inversely, as the Spaces
3. The Densities are inversely as those Spaces
4. The Elasticities directly as the Densities.

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(Art 338) The Barometer is a measure of the density of the atmosphere. If we ascend to any considerable height a sensible difference will be perceived in the height of the Barometer. The air being less dense the Mercury must fall; even the height of Arthur's Seat makes a difference of about 2 inches in the height of the Mercury of the Barometer.

(Art 339) Suppose in going up a height of 900 feet the Mercury in the Barometer falls $\frac{30}{100}$ that is if it stood at 30 at the bottom it now stands at 29 inches, if then we ascend other 900 ft. the Mercury will then fall another $\frac{30}{100}$ of what remains after the first 900 i.e. $\frac{30}{100}$ of 29 &c. so on in constant proportion every future addition.

(Art 340) Let us take an example of this as in the calculations of General Roy. Whenever the temperature is at 32° it has been fully ascertained that $m = 10,000$ and the sum will then express the height in fathoms. Suppose then $b = 36$ inches & we are ascending to the top of a hill we

[illegible]

(416)

find that the Mercury has sunk to 29.5

then find the Log: of 30 = 4771.2

each as is done here Log: 29.5 = 4698.2

This as we shall find is 73.3 fathoms

a very nice calculation 439.8 feet

but many corrections require to be

made to give us the exact height. A

correction as we shall find must be

made for the temperature of the Mercury

itself, for that being rarely the same

in the 2 Barometers a reduction is ne-

cessary

(342 Art) For illustration we shall

now go thro' an imaginary case of

Barometric measurement

suppose ^{inch:} 30 & 60° { 32° = the fixed temp: then

27 & 50° {

55 = mean of 60° & 50°

 $\frac{32}{23}$

23° according to the centigrade scale

reduce it to Fahr: by taking $\frac{5}{9}$ of 23° which $\frac{23}{5}$ then Log. of 30 = 4771.2

9) 115 then Log. of 27 = 4313.6

 $\frac{12.7}{12.7}$ 0457.6

00441 056

 $\frac{12.7}{12.7}$ 2742

3087 2285

882 25.592

441 0457.6

056007 25.59

height in fathoms = 482.996

do in Feet = 2897.94

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(Art. 343) Even here at the small height
 of ~~Barthens~~ ^{Barthens} ~~Leat~~ ^{Leat} the Barometer acti-
 =ally varies 2° between the top & bottom.
 Fahrenheit scale falls about 1° in as-
 =cending 270 feet. And it is a curious
 fact that ascending 270 feet or a degree
 of Fahrenheit is just equivalent to the
 climate 60 miles nearer the pole or
 a Geographical degree -

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Pneumatics

Sect. 1.

Air as Retarding or Accelerating Motion. In this Sect. we shall consider Machines for Raising Water; Motion produced by Gunpowder. Bodies impelled by Wind. & the Resistance of Air to Projectiles.

Machines for Raising Water.

(Art 347) The Siphon is treated of here. The cause of the flowing of Water in the Siphon is that a vacuum is supposed to be formed at the top or bent part of the tube, which is filled up by the Water in the Vessel from the pressure of the Atmospheric Air.

(Art 348) Gives an account of the Air Pump - It was invented by Otto Guericke a Gentleman of Magdeburg in Germany.

The Air pump is a machine now so common that I will not take up your time with any further detail but proceed to that interesting Machine the Steam Engine - You will find all the principles of the Air pump laid down in your text book.

(Art 355) contains a description of the Steam Engine which is as follows: See also the Improvements of Mr Watt (Arts: 357-8-9) The figure for showing the Theorem & Principle of Mr Watts Double Stroke Engine - is the following:

Motion by Gunpowder.

Art 361) The Air or fluid produced by the explosion of Gunpowder is permanently Elastic, & is ready instantly to expand with an enormous force. By Mr Robins this force was calculated to be 1000 times greater than that of common Air, also 250 times denser than common Air. So that its density is the fourth of its Elasticity $1000 = 4 \times 250 = 1000$ - In the acceleration of a Ball by the fluid thus generated 3 circumstances must be attended to (see Art 362) 1. 2. & 3.

Art. 363) The Balistic Pendulum invented by Mr Robins for determining the velocity with which Balls are projected by Ordnance of different kinds

Resistance of Air to Projectiles.

(Art 372) This shows the great difference of Theory & Practice by the former we should be led to conclude from Hydrostatics that it is as the Squares of the Velocities, but it is found very different by experiment. Leaving you to consider this & the two following Arts. we come to

(Art 375) This is the great Problem in Gunnery of which no one as yet has given an adequate solution. An approximation is made to it by Newton in the 2^d Book of his Principia, & in this he displays a most inconceivable power of mind. The 1st & 3^d Books are in general most read, but in the 2^d he really displays almost greater ingenuity than in these. It was in the 2^d that he laid the foundation of his doctrine of Fluxions, following his principle Euler & the French have almost given complete solutions of it, as may be seen in the Elements of Geometry of the latter. If we have a horizontal plane AB

AB

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The declivity of a hill, let the Gun
be fixed at different stations 1, 2, 3, 4 &c.
so as to strike against the hill at
1, 2, 3, 4 &c. when we wish to determine
a point, take $A A'$
= $A 1$ draw a paral-
= $l e l A B$ & another
to the plane 2, 2', this
is the second point, $A A'$
so with the 3rd &c. The curve will come
out to resemble somewhat a Hyperbo-
= $l e a$, of which a perpendicular $B C$ is
the asymptote. This however is not
an experiment for an individual
but for a nation, should w^d be the case,
Expence. No theoretical subject w^d be so
put to actual experiment w^d be so
highly advantageous as this.

Bodies impelled by Currents in the
Aether sphere, or by Winds -

is what we are now to consider.

$f = a^2 v^2 \sin. i \times m$, f being the impulse
of a stream of air; m is determined
by experiment.

(Lect. 368) 369-70)

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Sect. II

Air as the Vehicle of Sound or
Vibration of Sonorous Bodies.
 (Art 377-8) The figures which a
 Musical string assumes in its
 vibrations are a series of cycloids.
 of these the construction is very simple.
 (Art 380-1-2-3-4)

Propagation of vibrations in the Air.
 (Art 385, -6, -8, -9, -390, -1, -2,)

Sect. 3.

Air the Vehicle of Heat & Moisture.
 (Art. 393, -4, -5, -6, -7, -8, -401, -2, -3,) There
 is a certain height above the Earths
 surface where there is continual
 frost, where snow lies the whole year
 round, this height extending over diffe-
 rent parts of the Globe is termed the
 Line of perpetual Congelation - This
 Line is higher at some places on the
 Earths surface than at others: in some
 Northern Counties it is lower, about 5000
 feet is considered as the Snow Line
 in the Northern parts of Britain, but as

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no part extends to such a height. The Snow Line does not appear in Britain (Ben Nevis the highest Summit of Britain being but 4350 feet) In the Pyrenees the Snow Line is 9000 feet high - Such is the case with the Alps & the Peak of Teneriffe. When we go North however to Iceland we find it not above 2900 & in Spitzbergen it is only 2500, above which there is continual frost & snow all the year round - In some places however much nearer the Equator there is continual frost on the surface as at Spitzbergen over the Glaciers of Savay where there are as it were a continued series of Ice Hills -

(Art. 404, - 5, - 6, - 9, - 12, - 13) The heat of 100° is rare, at Pondicherry in Madras the heat is at the Medium = 88° at Senegal in Africa = 94° , at others in Africa = 111° and at some parts of Prussia the heat = 140° -

The most remarkable temperatures are to be found at Quito in South America 13° South. The Town stands on a height that is 9,280 feet from the level

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of the Sea. Vis therefore from its height
 in a delightful climate, being just
 like the Climate of places 54 degrees
 north. As we descend we experience
 all the changes of climate, fruits and
 herbs change, from partaking of the
 cooling productions of the North we
 come by degrees to taste the home-
 lies of the East. Nature is changed,
 with her of course, climate, soil, &c.
 In Winter we behold in Luto Snow
 & Ice, but on descending we can see
 on the same day all productions
 of Summer! The mean Temp. of the
 whole Lakes surface may be taken
 at 58° . The greatest Summer heat is
 140° & the greatest natural cold -40° .
 (ch. 414) We are told also in Scripture
 (St John cap. 18. 18) that (at our Saviour's
 condemnation in Syria) "The servants
 & officers stood there who made a fire
 of coals, for it was cold" This if the matter
 had not been there wd never have been
 done in such a country. Ovid also
 mentions a fall of snow at Rome both

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Black & White. A Bull of one of the
Popes also is on record which permits
persons if possible to land on Greenland.
The subject of Climate is very inter-
esting. Climate has been particu-
larly judged of from considering the
animals which formerly inhabited
a country. The England Bones of the
Elephant have been repeatedly found.
In Siberia the bones of many tropi-
cal animals. This presents a curious
revolution in the animal Kingdom.
Fast numbers of Beasts of Prey have
also been found in countries where
now they are totally unknown. The
Wolf & Bear were formerly inhabitants
of Britain. Both however are now
completely extirpated.

Under this Sect. is included Rain
on this we shall be very brief. The
vapour that rises from Waters uniting
itself with the air ascends into the higher
regions of the Atmosphere & is carried to
greater distances. This when dissolved
comes down in the form of rain owing
to the vapours becoming very dense.
It happens also from 2 clouds with

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rain coming in contact. Various instruments have been invented to measure 1. The quantity of humidity in the air at any time. 2. The quantity of rain which falls at any place in a certain time. These are the Hygrometer & Pneumometer.

Kind

(Art 415) - 416 & The other Articles -

We now proceed to consider the 3 interesting subjects which remain Magnetism, Electricity & Galvanism.
 & let us proceed to consider

Magnetism

A hard Mineral of a dark grey or brown color sometimes almost black has been termed a Natural Magnet or Load Stone. This Mineral is naturally possessed of certain singular properties which have therefore been denominated Magnetic properties. These properties may also be communicated to Ferruginous substances which are then termed Artificial Magnets. Whether Artificial or Natural a Magnet is always possessed

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of the following distinguishing properties.

1. It attracts Iron & other ferrug. bodies.
2. When at perfect liberty it invariably turns the same part of its surface towards the North Pole of the World or towards a point not much distant from it, & of course the opposite point to the South. These 2 points are called its poles the former the North the latter the South Pole.
3. When 2 Magnets are placed so that the N. P. of one is opposite to the S. P. of the other then they attract each other. But when in an opposite situation repulsion takes place.
4. When at liberty the Magnet generally inclines one of its Poles, this is termed the inclination or dipping of the Magnet.
5. Any Magnet may impart these properties to Iron or Steel.

The Magnet is in general in the shape of a Horse shoe. The variation of the Magnetic Needle at present is always about 27° to the West, so that it does not point due North, this must therefore be allowed in calculations. In 1657 in this country

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it pointed due North; since that time it has been constantly varying to the West. A piece of Iron or steel brought within certain distance of one of the poles of a Magnet (artificial or Natural) is attracted by it, so as to adhere to the Magnet & not to be separated from it, but by considerable force. This attract: is mutual, both equally attracting each other. This force of Magnetic attraction varies in different circumstances. Hard steel or Iron ores are attracted less forcibly than soft steel & the latter less forcibly than Iron. If a piece of Iron presented successively to the different parts of a Magnet, the attract: will always be found the strongest at the poles of the Magnet. The attract: is always strongest at the surface of the Magnet & diminishes as the distance increases. It is remarkable however, that notwithstanding the numerous experiments instituted, the Law of this diminution of attract: has never been ascertained. Some have found it diminished as the Square of the distance while others have affirmed that it is in proportion

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to the cubes. It is certain however that the attractive force decreases faster than the simple ratio.

Magnetic Repulsion takes place between similar poles of different Magnets. The N & S poles of one Magnet repel the N & S of another but the N & S of one attract inversely the N & S of another Magnet. A piece of Iron brought within a certain distance of a Magnet becomes itself a Magnet & presents the different phenomena of polarity. The Magnetism which is acquired by soft Metals in this manner is lost immediately on removing them from contact, but it is different with hard Metal.

From these facts we may deduce the 3 following collections.

1. That there is no Magnetic Attraction but between the contrary poles.
2. A Magnet attracts soft Iron much more forcibly than hard because the latter retains it longer the latter does not so soon become Magnetic.
3. That no Magnetic repulsion can take place, but between poles of the same name. Neither Magnetic Attraction or Repulsion is in the least diminished, or otherwise affected by the interposition of any sort of bodies except ferrous.

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Heat weakens the power of a Mag-
net, a white heat almost entirely destroys
it. The attractive force of a Magnet may
be increased considerably by gradually
adding more Iron weight to it. Among
the Nat: Magnets the smallest generally
possess a greater attractive force in
proportion to their size, than those which
are larger. Magnets of above 2 lb weight
seldom lift up ten times their own weight
of Iron. It also frequently happens that
a Nat: Magnet cut off a large loadstone
often possesses greater attractions than
the original Stone from which it was
taken. This I suspect owing to the
heterogeneous Mass of the original of
which the piece cut off may be purer
than the rest. Various metals show an
attraction towards Magnets till they
be hammered. Such as brass. Platina.
The Mag: attract: is often increased by acids.

Let us now proceed to consider the
Mariners Compass. When a Magnet
having 2 poles be freely suspended or
if it be placed to float on Water it will
direct its poles North & South & this in
every quarter of the World. This wonderful
property is the most useful part of the
subject of Magnetism. It is this property
that

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enables the Mariner to steer thro' the
 trackless ocean. An artificial Magnet
 fitted for this purpose in a proper box
 is called the Magnetic Needle or Mar-
 iners compass. The Needle however does
 not point directly North & South but
 there is a degree of variation either East
 or West which is termed the Declination
 of the Needle. This Declination since
 1657 has been continually increasing
 to the West previous to this it was East.
 At present the declination or variation
 is 27° West. Besides declination, the
 Magnetic Needle suffers also a degree
 of Inclination. This is very evident at
 the Equator where it is equally removed
 from both poles the Magnetic Needle
 stands horizontal but the more we
 approach either the N or S the more
 will the N & S pole of the Magnet be
 inclined, in that direction. If the Magnet
 were placed over the Magnetic poles
 of the World it wd just stand perpendi-
 cular to the Earths surface there. In
 London about the Year 1576 the N. pole
 of the dipping Needle stood $41^{\circ} 50'$ below
 the horizon in 1775 it stood $72^{\circ} 3'$ the
 whole change during so many years

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amounting to less than a quarter of a degree allowing the accuracy of the observation.

Various tables have been calculated of the different degrees of inclination which this needle presents in different parts of the Globe & on different Mercators Projections they may be fairly marked out with considerable accuracy. They are remarkable in the Indian Ocean.

I shall conclude this Lecture by briefly considering the

Theory of Magnetism

That the Earth acts as a great Magnet is satisfactorily indicated by various facts. The great consideration is to know the cause which in a Magnet of whatever sort it be produces Attraction & Repulsion. See

Human ingenuity has contrived abundance of Hypotheses in explanation of these phenomena. Here I shall only mention one, which is very similar to the Franklinian Theory; it is the Theory of Despinus. He is of opinion that there exists a fluid productive of Magnetic phenomena. That this Magnetic fluid is so subtle as to penetrate the pores of all bodies of an Elastic nature & its particles

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repulsive of each other. He farther supposes that there is a mutual attraction between this fluid & Iron or other ferruginous bodies, that no other substance has any action with this fluid.

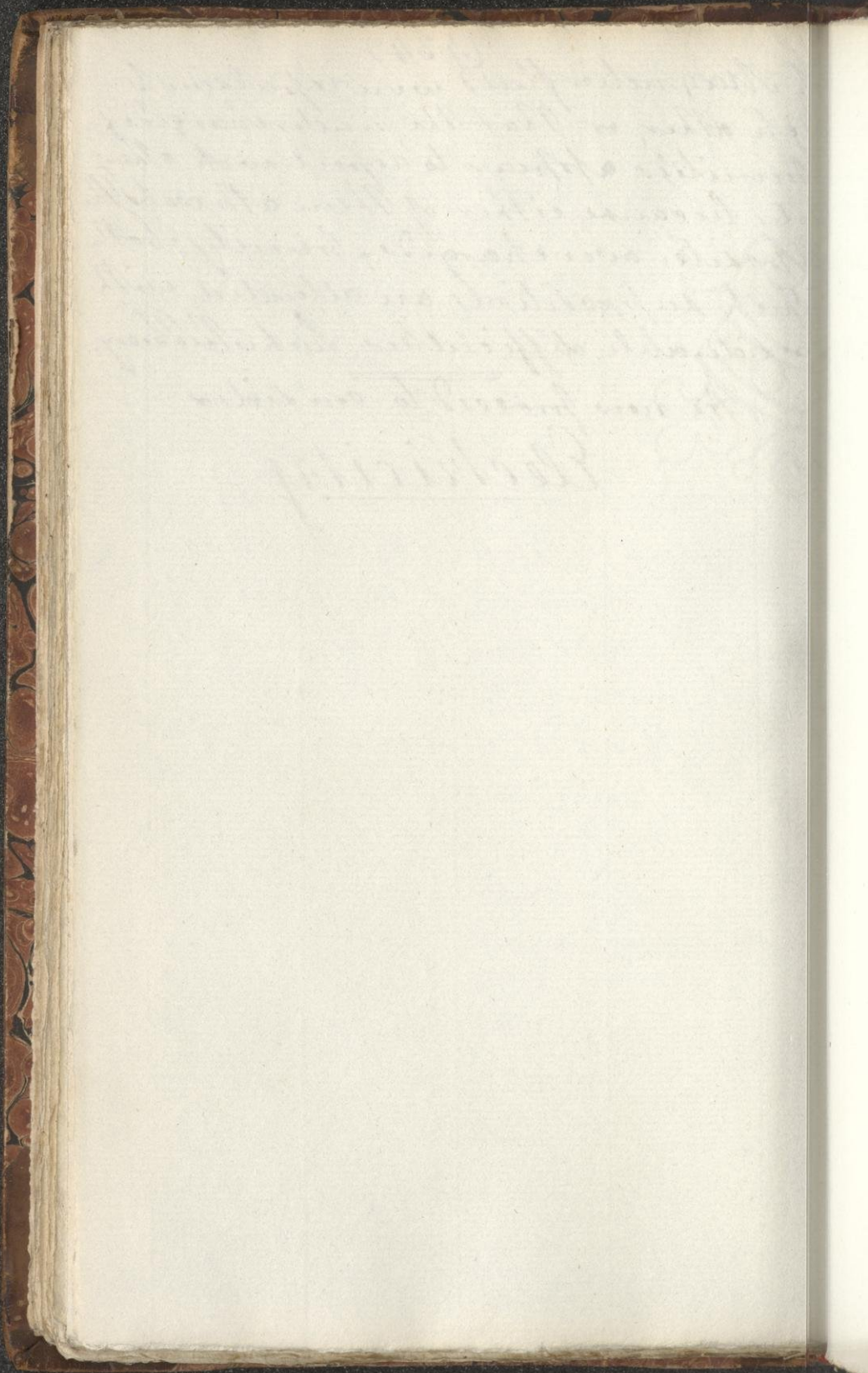
According to this hypothesis Iron & all other ferruginous Bodies contain a quantity of Magnetic fluid equally dispersed thro' every part of them. In this state they show no repulsion or attraction because the one balances the other in such cases these bodies are said to be in a natural state. But when in a ferruginous body the quantity of Magnetic fluid is driven to one end then the body becomes Magnetic, the one extremity being overcharged the other undercharged with this Magnetic fluid. There is an attraction between the overcharged extremity of the one & the undercharged extremity of the other Magnetic body, on account of the attraction between the Magnetic fluid & the matter of the body. But to explain the repulsion between the undercharged extremities we must either imagine that the particles of these bodies were deprived

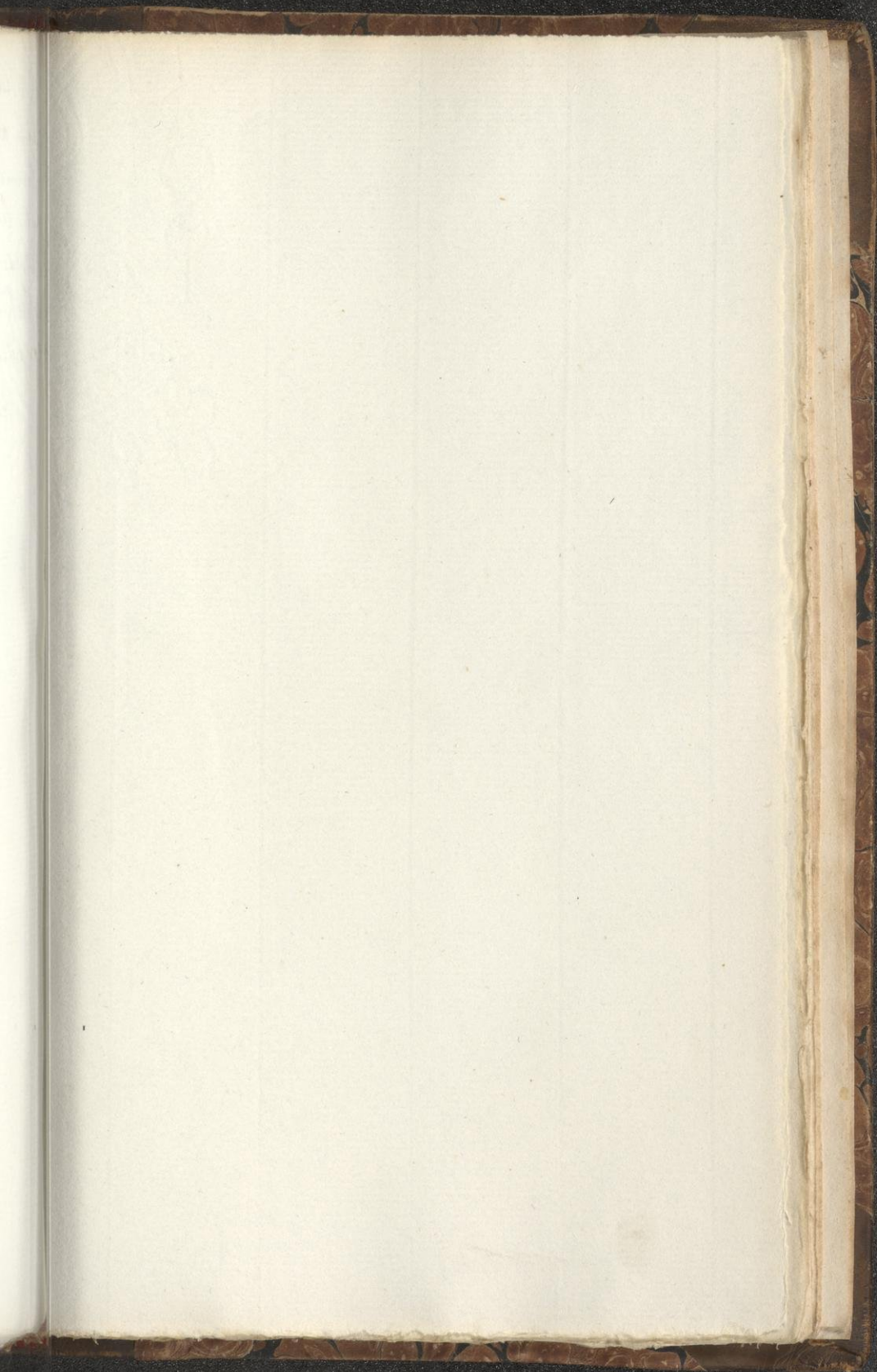
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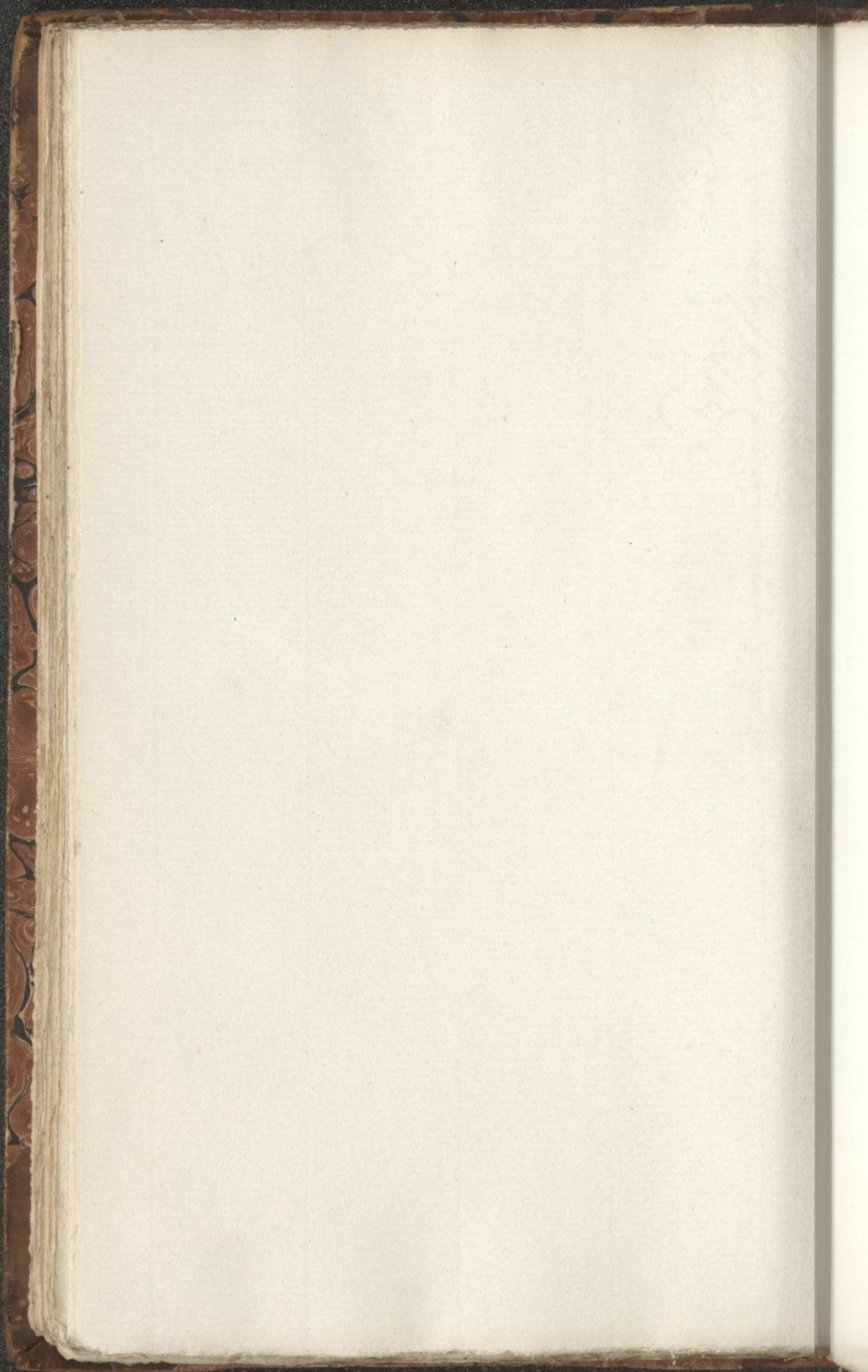
of Magnetic fluid were repulsive to each other, or that the undercharged eximities appear to repel each other only because either of them attracts the opposite overcharged eximities, both which suppositions are attended with considerable difficulties. Such is the theory.

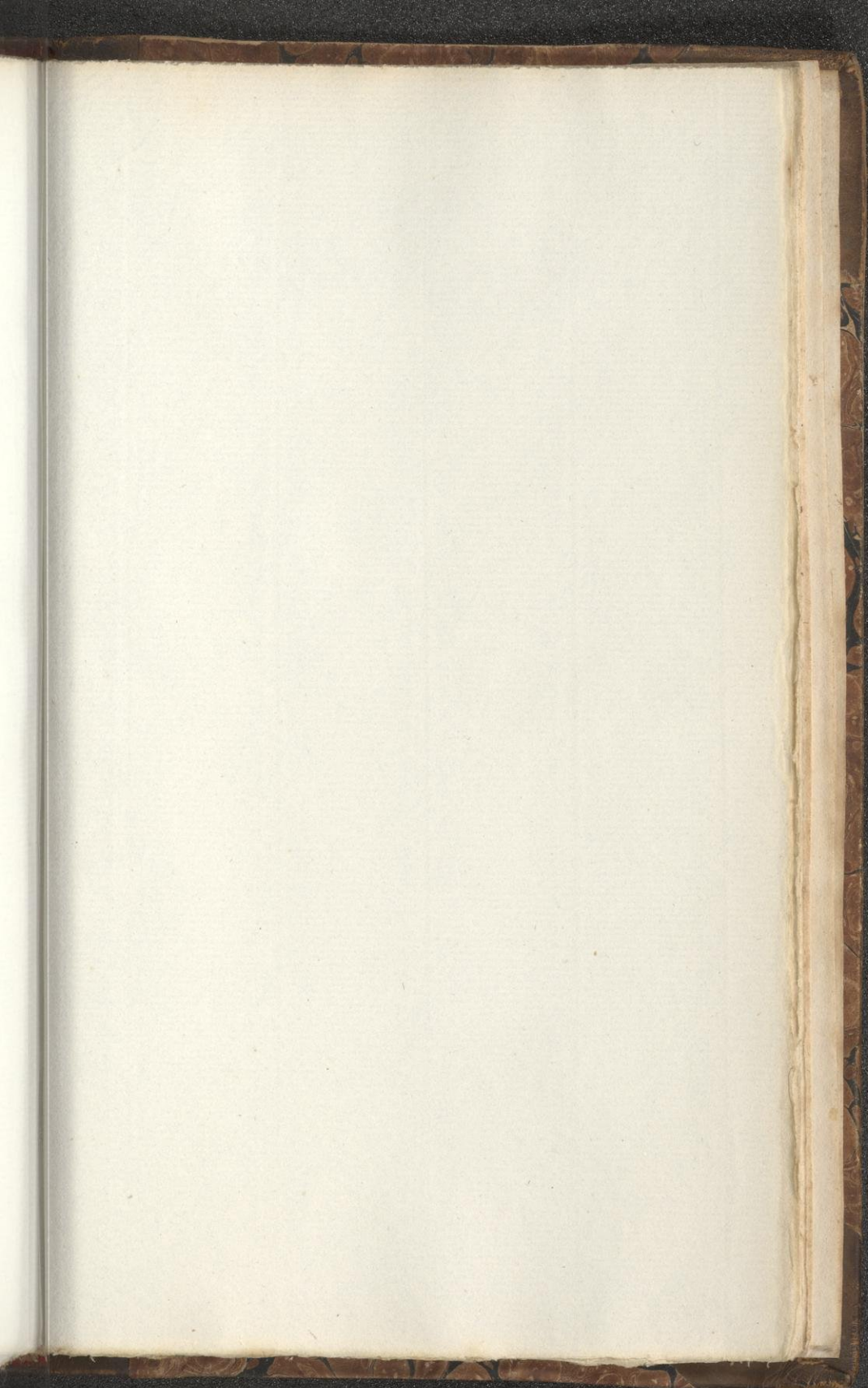
We now proceed to consider

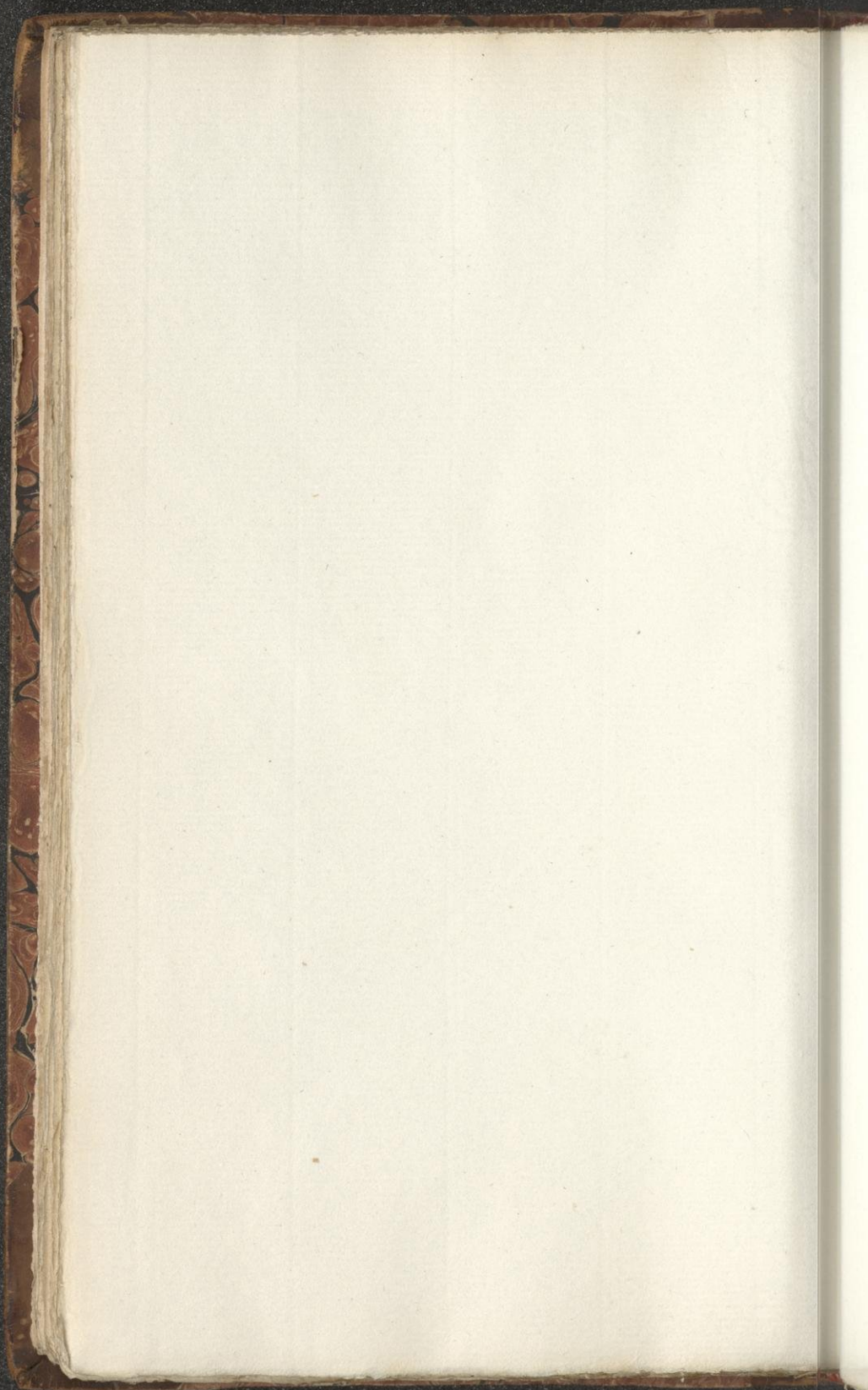
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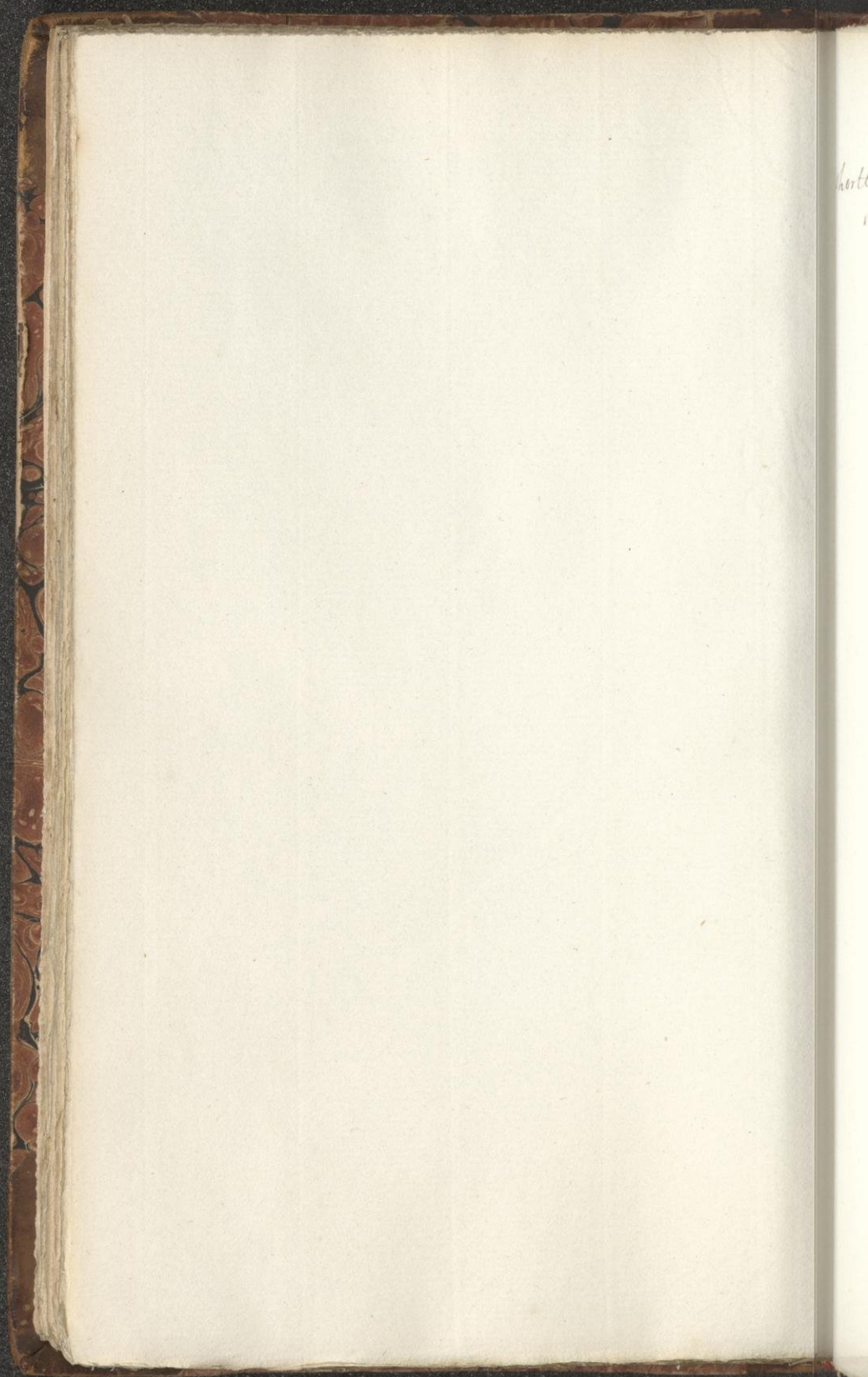








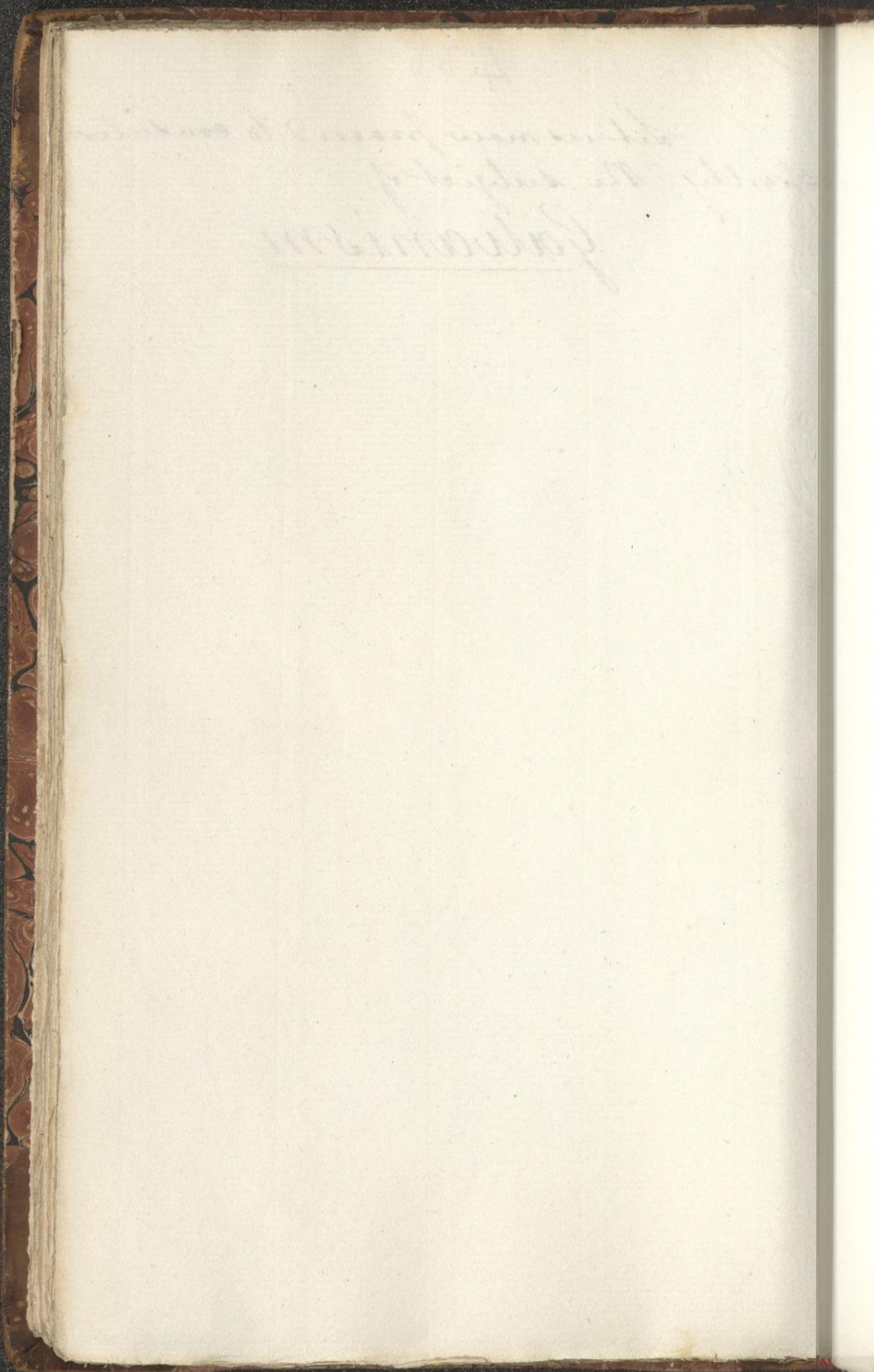




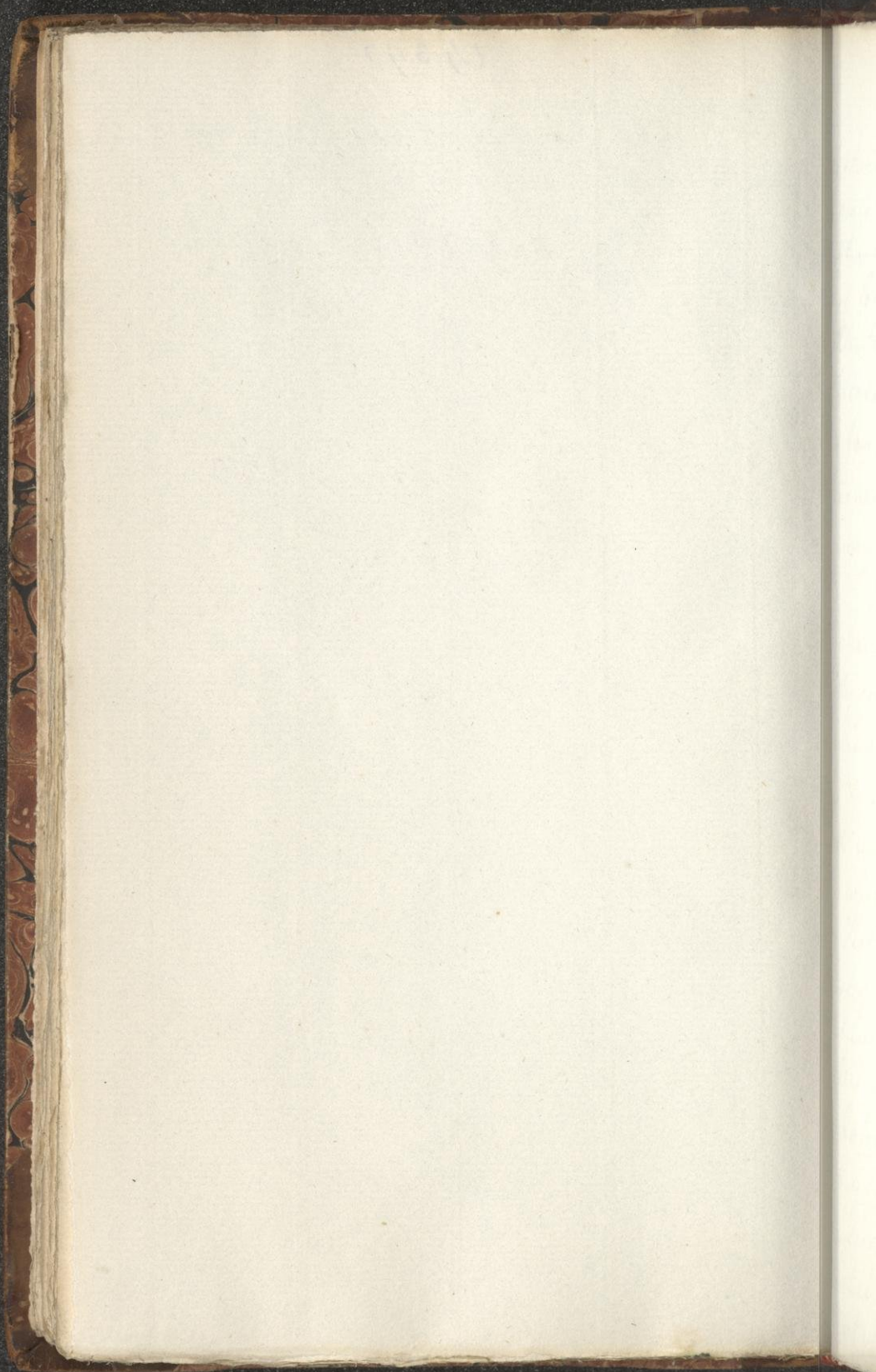
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Let us now proceed to consider
shortly the subject of

Galvanism



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In concluding these course of Lectures, which I have been delivering to you during this Session, I cannot better occupy your attention in this my last Lecture than in directing your attention to those Books on Natural Philosophy, which I can recommend as furthering your knowledge of this Science; & in giving you a short summary of Matter in General -

In accurate Language Matter properly signifies the Substance of which body consists & was by the Greeks denominated χυμν. With regard to Matter the Laws of Action may be well divided into 2 great divisions. 1. The powers by which Matter is aggregated or united. 2. That by which it is separated. The first of these divisions may be subdivided into 4 separate species and are called the powers of Aggregation. 1. Cohesion, 2. Chemical Affinity. 3. Crystallization, 4. Gravitation. The second viz. the power by which the particles of body are separated is chiefly Heat which separates both states of body

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Mathematical

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vis. The states of Impenetrability & Fluidity. The latter being Elastic & Liquid. What is termed Impenetrable in Matter is figured & extended, both are incable of figure & extension.

We shall proceed with The subdivisions of aggregated or united Matter. Cohesion. The attraction of cohesion is that attraction which subsists between homogeneous particles, that is, particles of the same body. It acts therefore at small distances. It is the power of cohesion that prevents a piece of Iron for instance, from coming to pieces, & this is contrary repulsion in the particles of the same Mass. The force of cohesion may be expressed well in an algebraical form. Cohesion powerfully modifies the extension & action of Chemical Attraction & is an Antagonist to the power of Heat. The attraction of cohesion is not exerted in an equal degree in all bodies. Iron & all Luminous bodies have it in a considerable degree whereas metallic substances have it in a weak. The most powerful agent against the attraction of cohesion is Heat which separates its particles

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Vols says The Cohesive Attraction. If the heat be increased the Attraction of cohesion is in time lost & the substance an elastic or æriform figure.

The same changes are produced by the action of Chemical Affinity. Thus if a liquid be poured on a solid substance it often happens that a mutual attraction is exerted between them in consequence of which the Aggregation of the Solid is subverted, its particles are detached & uniformly diffused thro' the liquid so as to be no longer perceptible. This is the Chemical process called Solution. When now these powers whether of heat or Chemical Affinity are withdrawn Cohesion resumes its force & the body returns to the solid form. When cohesion resumes its power more slowly the particles are not united indiscriminately but in uniting assume a particular arrangement & thus form masses of regular figures, bounded by plane surfaces & determinate angles.

When cohesion is exerted in this manner with this result the operation is called

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2 Crystallization - The form which different bodies assume are various. Some philosophers however De Lisle for instance considers all these forms as secondary. He considers the whole to arise from certain truncations. Thus the cube truncated produces the 1st on the angles which are 8 in number & the 6 sides a 14 faced figure. 2. If it be truncated on the edges which are 12 in number that with the 6 sides forms an 18 sided figure. 3. The facetter under it a 4 sided prism. Thus on the principle of truncation many varieties are formed. De Lisle considered the primary forms to be 6 in number from which all others may be truncations & as easily deduced. 1. The Tetrahedron 2. The Cube. 3. The Octahedron, 4. The Rhomboidal Octahedron. 5. The Rhomboidal Parallelepipedon. 6. The Dodecahedron with triangular faces.

The doctrines of primitive forms were afterwards very much improved by Bergman & Gahn of Sweden & chiefly by Haüy of Paris. By them it was ascertained that crystals however they might

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differ in external appearances had a primitive form or Nucleus centred in each & to be obtained entire by chipping in proper directions. This forms the basis of Haüy's System of Mineralogy. He reduces the primitive forms to six & not differing much from those of De Lisle.

As to the reason why 1. Any Bodies in Nature assume these Sym-metric forms. 2. Why there is a diversity in the form. 3. Why the same body has a particular diversity of form; no satisfactory explanation has yet been given & I fear is a circumstance of which we merely know the fact, without much hopes of ever discovering the cause.

The other species of Attraction is the 3 Chemical Affinity - This is exerted between particles which are at no sensible distance from each other; & the particles must be heterogeneous. This last circumstance distinguishes it immediately from Cohesive Attraction. There immediately occurs a change in the constitution & properties of the

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substances employed. This forms the great feature. With respect to the Cause of Chemical Affinity or rather of the change produced by Chemical Affinity we are quite in the dark. Sir Isaac Newton with all his Mathematical & Mechanical powers could never succeed in pointing out the true cause. Berthollet has likewise speculated much on this point but with no better success. The next power of Aggregation is

4 Gravitation. It is evident that great specific Gravity in any substance having much Cohesion & of sparing solubility must cooperate with these substances in producing great firmness & consistency of particles. It must evidently diminish the power of other substances in decomposing it & of course separating its particles. The Laws of Gravitation have been amply unfolded by the Immortal Newton. From him we have learnt the Union & Harmony which Gravitation produces in the various parts of Creation; here we learn

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(447)
That Gravitation is the basis on
which the Universe is founded
& that by it all is preserved from any
confusion or irregularity. Kepler
also has unfolded to Mankind
many of the Grand Laws of Nature.
viz. That the Areas of the Spaces
are as the cubes of the distances.
Among similar wonderful & previously
unknown Laws. The second division
of Matter was into what is capable
of separating all the particles of body.

This separation of particles is
caused by Heat. This as has been
already hinted at is the most active
Agent in Nature. Nothing can
withstand its power, it forces
asunder the most cohesive par-
ticles of Matter & produces the de-
composition of the most refrangi-
ble substances. It is extended over
all Nature & has no dependence
whatsoever upon any other body for
its action. By this power then

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Matter is decomposed & disunited
 in its particles by cohesion & it
 is united or aggregated. With this
 imperfect view of Matter in General
 I now conclude these Lectures
 hoping however that you will not
 rest satisfied with the little know-
 ledge you have here gained but
 by close & unremitting application
 will add much to the Matter you
 have collected here -

Finis —

