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Brodie, William

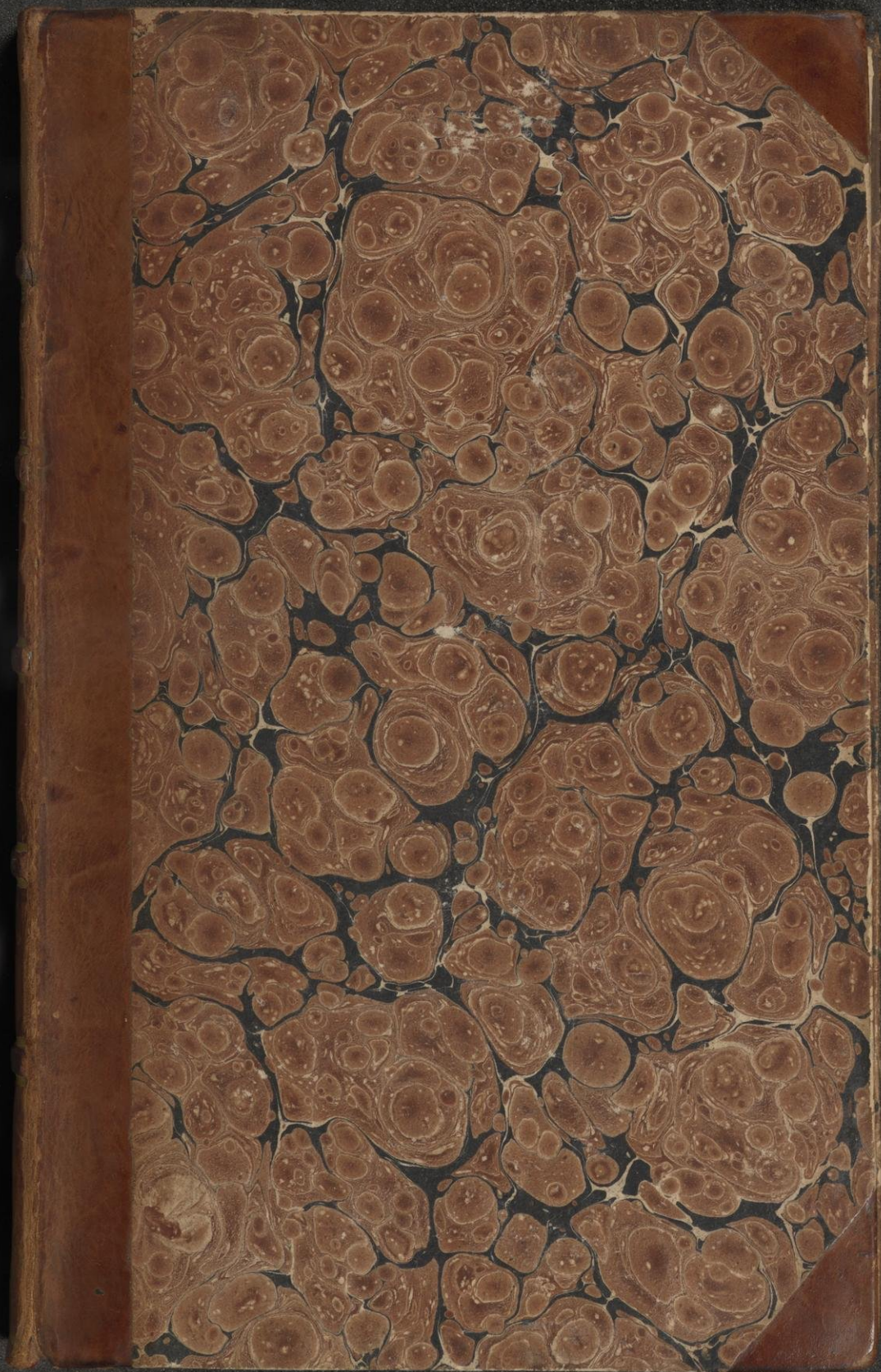
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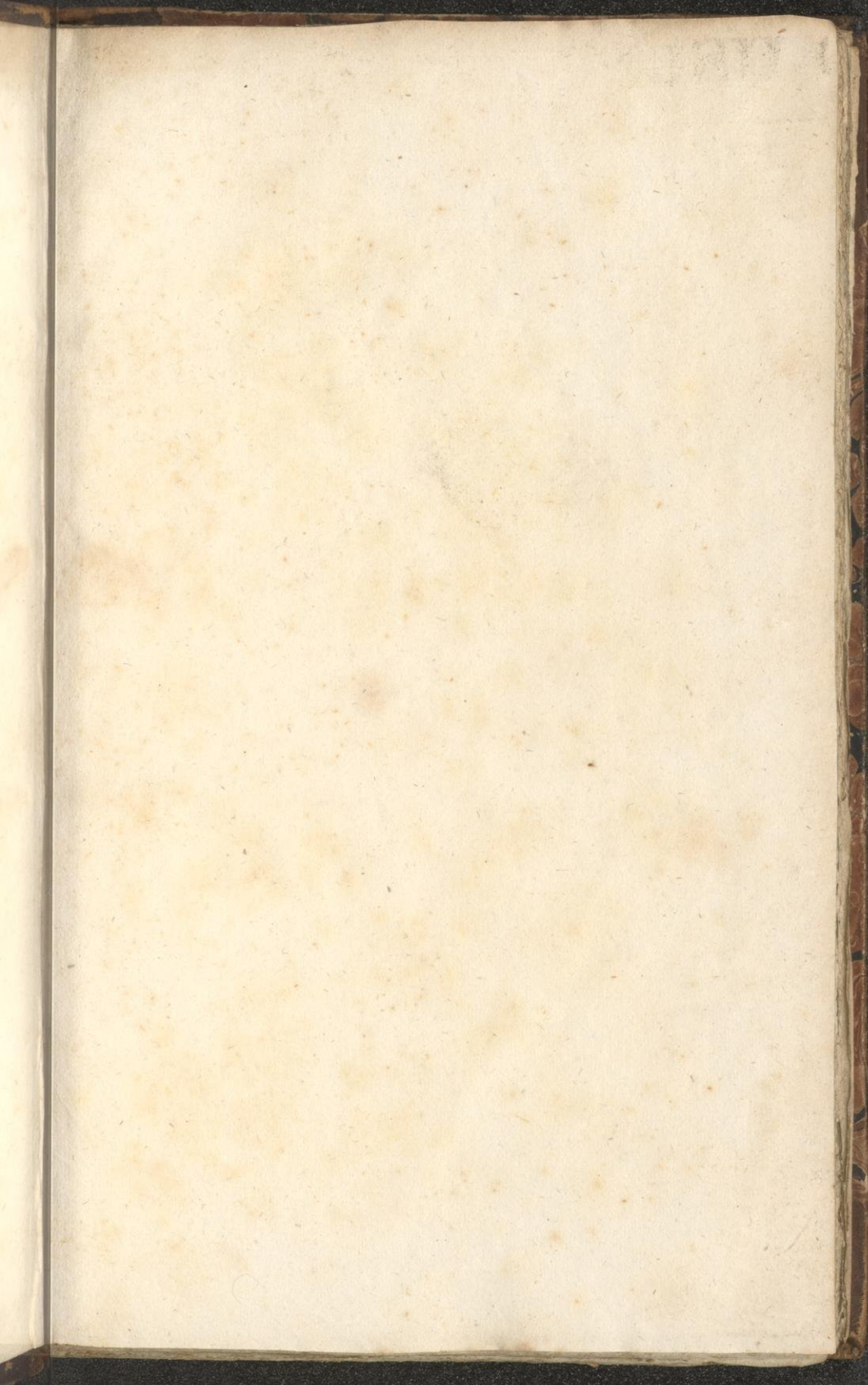
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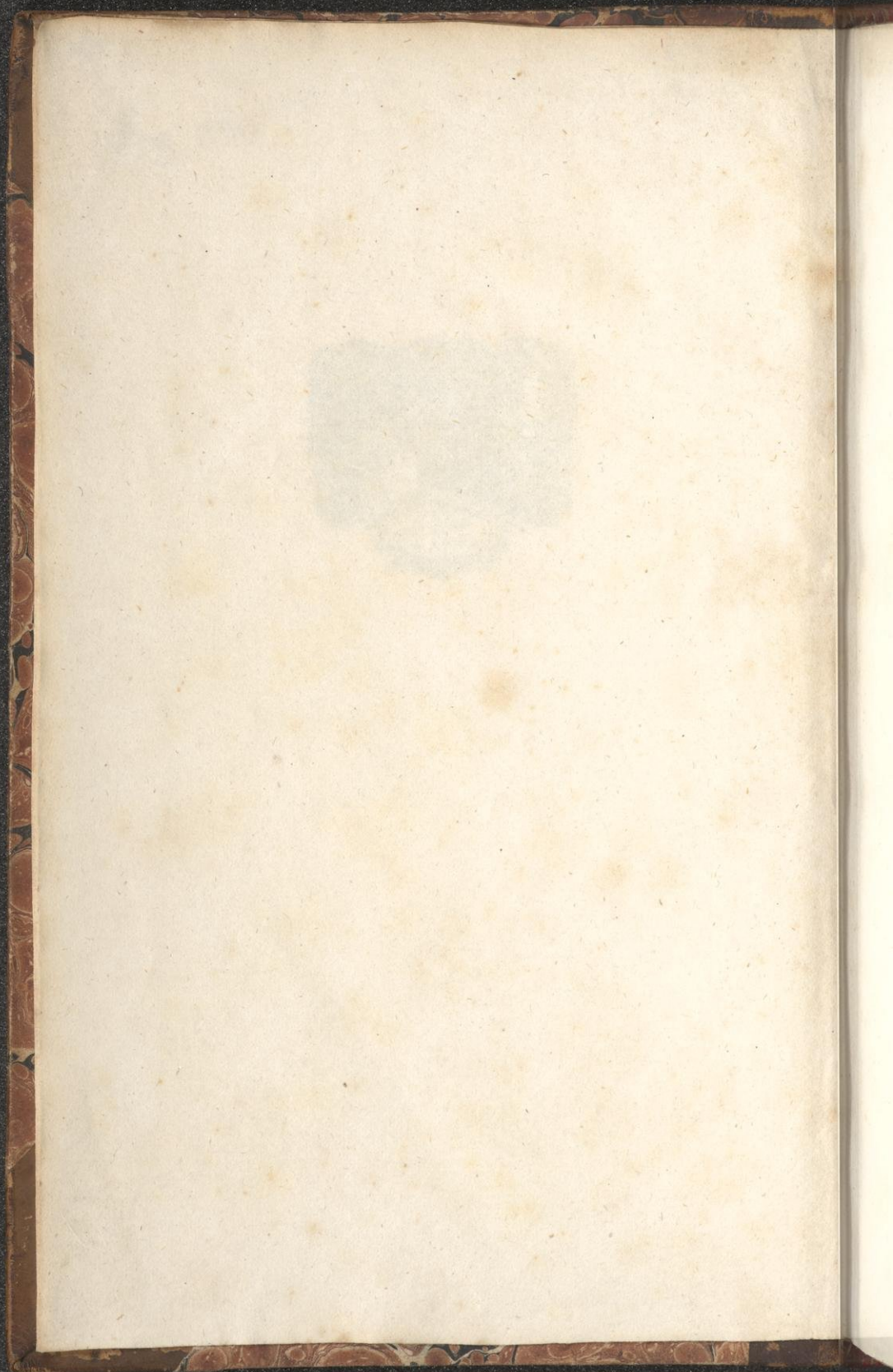
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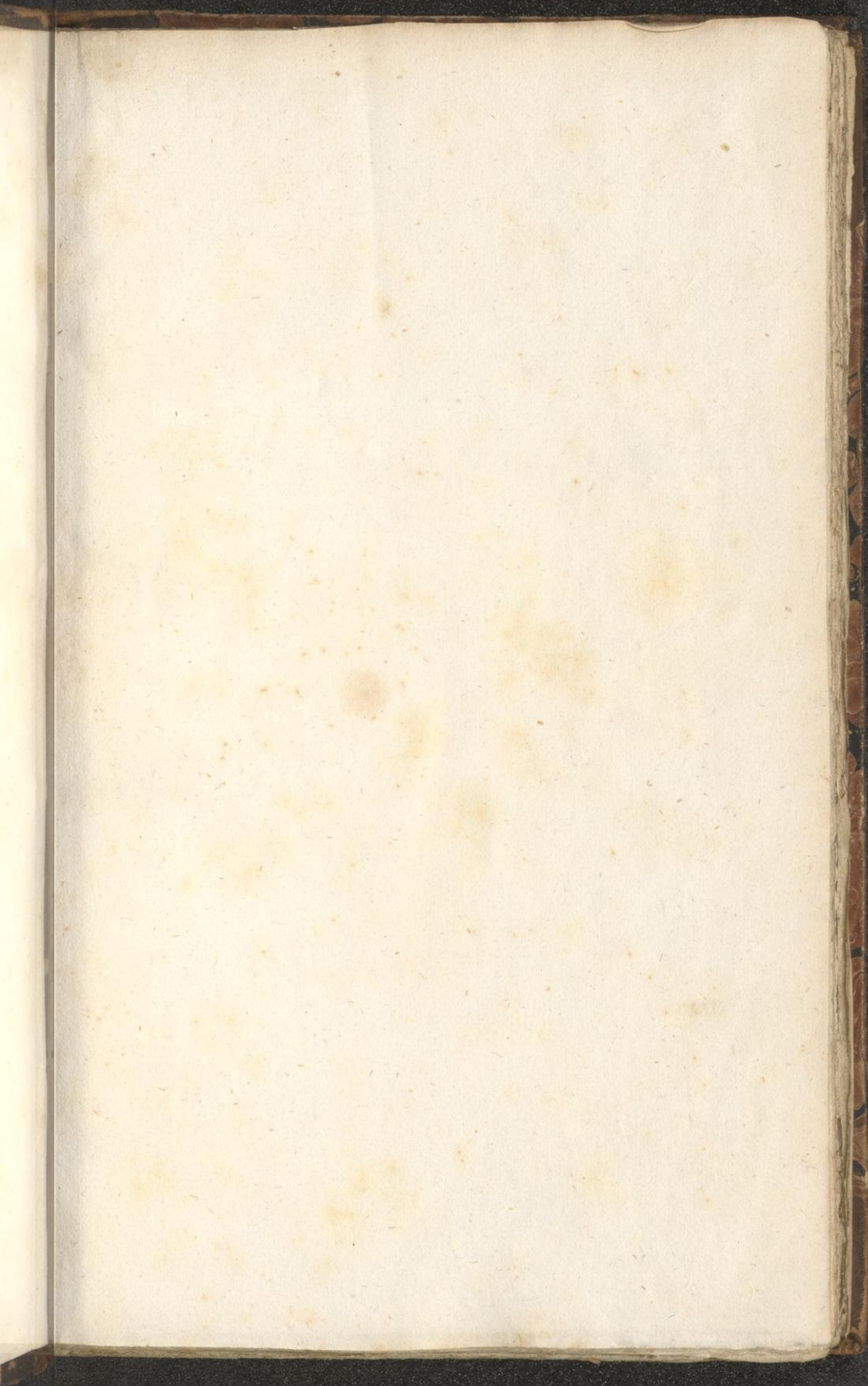


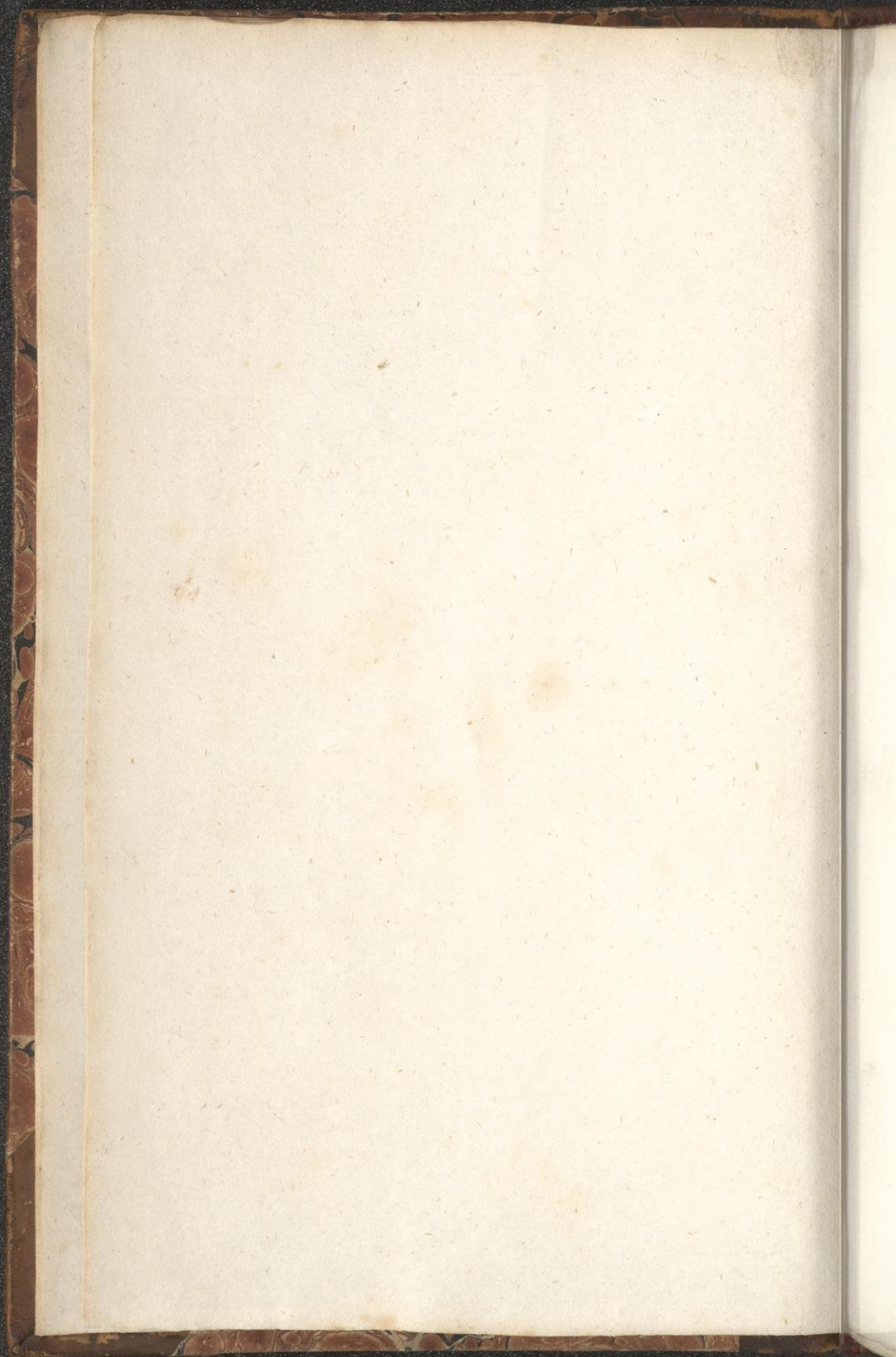
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Professor Hayfin's
Lectures

on
Natural Philosophy.

Vol: 1.

THE NEW EDITION

I
Nat

Introduction

*Professor Playfair's
Lectures*

on

Natural Philosophy.

Vol: I.

Wm. Brodie

1818-19

Edinburgh -

Geography, and

History

Natural Philosophy

Vol. I.

By J. Smith

1794

London

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On
Natural Philosophy

Lecture 1st
— 2 Nov. 1818

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There are in Nature two great things
doms of which the one relates to mind
and is termed Metaphysics, the other re-
lates to matter and is termed in general
Language Natural Philosophy—

422
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This subject which is to engage
our attention during the subsequent
Lectures, is one, the utility, as well as
amusement of which, is too well known
for any illustration, of this however I
shall hereafter speak. Every object in
the material world, is possessed of
extension, as an extent is distinguished
by 3 properties, every object in the ma-
terial world must be possessed of these
three viz. Length, Breadth, & Thickness.
The Science which treats of extension
is termed Geometry.

Geometry is commonly divided
into 3 branches viz Elementary,
Higher, & Transcendental.

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of ^{the} first or Elementary are such as
as either enter into all the rest & form
the basis on which they rest, such are
the Elements of Euclid. The second
or Higher branch treats chiefly of Curves
which are not included in those temple
Circles which enter into the Elements;
of spherical instead of Plane triangles.
The 3rd and last termed transcendental
treats of Infinity. This last is in some
languages which abound with superior
figures sometimes called the sublimest
Geometry. Such then are the 3 great
divisions whose end are to measure
the magnitude, position, and quantity
of Bodies. The measurement however
extends not alone to these three, but
also what quantity is included in
each, hence Arithmetic is included
in Geometry. This however after all
was not found adequate for the grand
purposes of Geometry, a new language
came therefore to be employed of most
eminent advantage. This was no less
than the unrivalled Algebra.

Arithmetic is of boundless utility
the decimal notation first gained from
the Arabians is even held in great
estimation. By the discovery of Alge
bra many and great were the advantages

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acquired. None difficultis insurmountable even by the powerful aid of Geometry. & Arithmetic were at length overcome by this noble discovery which is a part of Mathematical Education that ought never to be overlooked. There in Geometry, Arithmetic & Algebra, which however is only a particular kind of arithmetic form the bases of physical science. From the days of Euclid & Archimedes to those of Newton & Laplace Mathematics have been held in most deserved estimation & have always been rapidly advancing. The celebrated motto inscribed over the entrance of Plato's school ought to be engraved on every enlightened mind, as there is no doubtless no study from which higher or more lasting advantages can be obtained.

The next general properties of Bodies is that called Impenetrability. This is the property which prevents all other bodies from occupying the same space which it occupies. The third is Mobility or Capacity in that property of bodies which renders them capable of being moved, from one place to another. Lastly the property of Divisibility *ad infinitum*

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Philos

by which is meant that no part of matter
whatever can be conceived so small that
there may not still be a smaller. All these
properties are ascribed to the action of form
force or power which is the agent. There
is still another, and of all, the most im-
portant property of Bodies. Iman Attraction
which is of 2 kind, the Attraction
of Cohesion & that of Gravity. By the
former the various particles of one Mass
are made to adhere closely to each other
as in all matter is the case, by the second
distant Bodies are impelled towards each
other. Opposed to Gravity also is Impul-
-sion or that property by which Bo-
-dies are impelled forward; these act
at once on large Masses of Matter while
the other is limited to smaller distances
not producing motion at once. The
1st of these may be termed Integritant
the other Corpusculant action. The 1st
of these forms what is properly under-
stood by Natural Philosophy, various
changes may take place but the consti-
tution of the Bodies acted upon is never
in any degree deranged. While on the
other hand in Chemistry by the Analy-
sis or composition of any Bodies the
constitution & characters while in that
state are entirely changed. In Natural
Philosophy these forces act on large Masses

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of Matter or body. Both are conversant⁵
about genera & species which when
managed with precision are of very
extensive utility not only in these but
in every other study. No mind is pos-
sessed of so retentive a Memory as to recol-
lect precisely the various names of each
Object in Nature, all have therefore very
wisely been closed under various
heads from various similarities. This
is called Classification or Arrangement
and from the species (generally the
lowest term) we rise progressively to
the genus Order & Class.

In Natural History these clas-
sifications are particularly conspic-
uous. It was from these various
classifications of physical substan-
ces that Plato first derived his notion
of Ideas. He thus divided all bodies
in two kinds, Nature in Motion &
Nature at rest, not that they are abso-
lutely altogether at rest but are so in
our Minds. These have (as at present)
been divided into 3 great heads

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over the Mineral, Vegetable & Animal Kingdoms. This tho' the common division does not include every thing in nature, for instance Air & Water belong to neither of them; there are however very few exceptions and the division is by no means to be rejected -

According to common knowledge in Natural History we are so much indebted thus defines the 3 Kingdoms. The Mineral Kingdom (says he) is that "which grows; The Vegetable that which "grows and lives; The Animal that which "grows lives & feels". Of these however the 1st is far from being just, for it is by no means true; at least never has as yet been ascertained, that Minerals grow. Tho' in many moist places from the dropping of water with some portions of lime Stalactites are formed yet still this cannot be called growing. A Definition can only be here when its truth is evident to our senses; A more proper definition of a Mineral

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Therefore would be that which has for
its basis The Internal Structure of the
Earth. Geology the other branch of
Mineralogy relates to the various struc-
tures of the various strata of which
the Earth is formed.

The definition given of the 2^d
the vegetable Kingdom may be better
substituted by this, where instead of
distinguishing the 2 first by Animals
and inanimate we may term them
Organic & Inorganic. Thus if we
knock off a piece of Stone from a
large Mass, this bit struck off will not
change the least degree from what it
was when joined to the original Mass.
If however from a Plant or Tree we cut
off a branch it is immediately changed
it no longer preserves its verdure it
withers and dies being deprived of the
Sap with which it was before nourished
and thus said to be organic. Not only
the vegetable but also the Animal King: is said
to be organic, & Mineral inorganic.

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Air moisture & light are indispensable
to the nourishment of a plant. In Botany
may be well seen the infinite imperfections
of arrangement; then an Order class
Species Genera Species Varieties (Species)
The Physiology of Botany, constitutes now
over a branch of study not sufficiently
attended to. The explanation of phenomena
subordinate to this constitute the study
of Agriculture.

The Animal Kingdom are best
to be distinguished by their Stomachs
and that process of digestion which gives
them so clear a distinction, as also to
contrary motion. This branch of Bot.
History has been termed Zoology. Really
to the grandeur of the subject it is owing
that Buffon has written on this subject
alone, one of the most eloquent works
that ever appeared before the world, a
work which in eloquence may perhaps
in some instance have been equalled
but certainly never surpassed. And
that one of acute discernment &
and possessed of the highest natural

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endowments should have attained
to Eloquence is not to be wondered at,
for nothing is there to be found more
truly grand more wonderfully sublime
than the Orator, but chiefly his
mechanism of the human frame, a sub-
ject which an eminent Man says
might of itself form a subject for
innumerable volumes. It is by
this Internal Structure that this branch
is to be distinguished from the other
two, but chiefly by the Homœop, &
wonderful a part but which properly
belongs to the Anatomist to describe. It
is this branch of Knowledge that has
produced the numerous Physiologists
in the world, a subject which when well
conducted is highly interesting & instructive.

We have now in a slight man-
ner considered the 3 Kingdoms of human
knowledge in different circumstances,
we have considered the 3 great Kingdoms
of nature into which all mortal
matter may be resolved, let us now
come nearer to the subject of which

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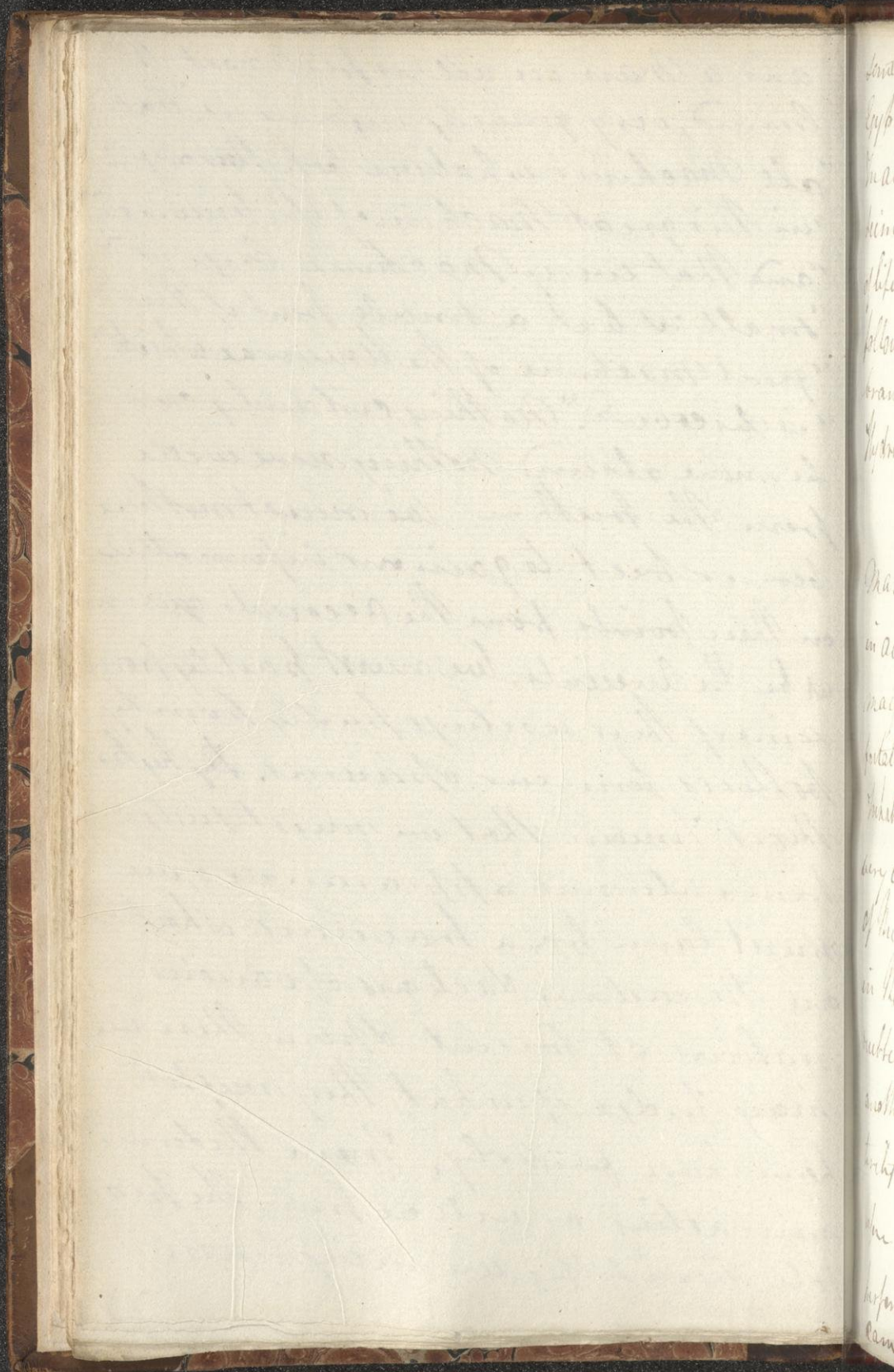
we are to be engaged, in this class, 10

The object of the present hour shall be to trace the origin & ^{progress} invention of mechanical invention from the earliest periods of its infancy down to the present times, in which it has arrived to so great a degree of perfection. The first steps of invention it is very difficult indeed impossible to know, it remained alone in the breast of the inventor and by him was employed to his own particular purposes. The Society was pretty well formed it was not to be known or recorded to after times. From Society alone then we are to learn these facts. The laborious task of tracing back Antiquity is a study of rather modern growth. The Ancients had many very absurd notions of the origin of the world for they in general paid little attention to collect the scattered remains of Antiquity but formed their notions more from the fancy of their own lively Imaginations than from any existing ~~authorities~~ authorities. Thus for instance veteris a most skillful mechanic

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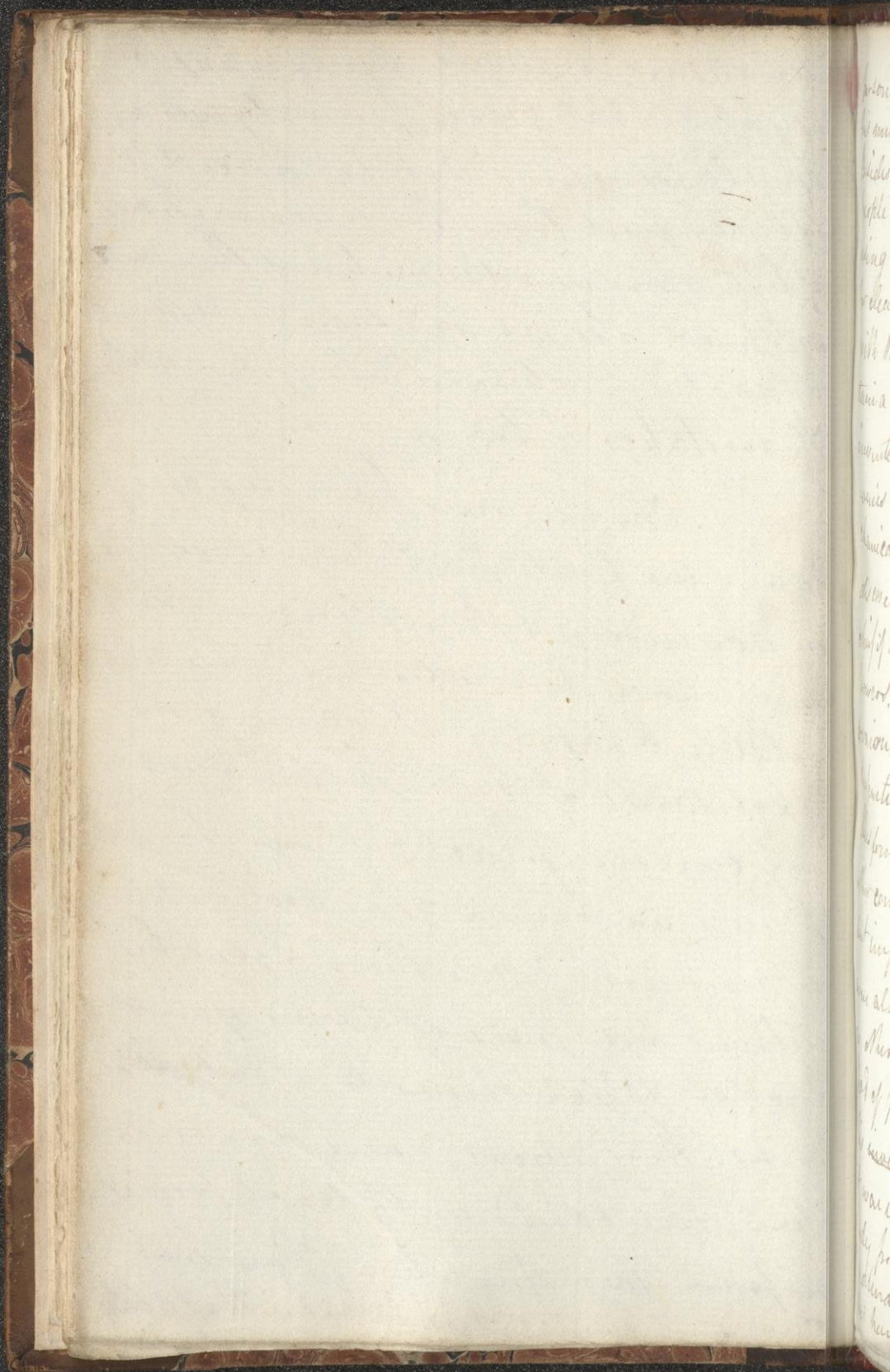
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and a Man in all respects not ill
learn'd, very gravely informs us, "that
"all Machines whatever took their origin"
"in this great Machine of the Universe"
"and that every Machine large or"
"small is but a small part of this"
"great Machine of the Universe which"
"is discover'd." No thing certainly can
be more absurd, nothing more wide
from the truth — We must therefore
be content to gain our information
on these points from the accounts given
us by the Ancients. We must partly borrow
some of their writings partly from hy-
pothesis form our opinions. By hypo-
thesis I mean that we must judge
from external appearances, we
must learn from travellers what
are the customs, fashions of various
nations at present. From these we
may judge of what they might
have been formerly. From the same
now acting as well as from the peo-
ple themselves we may learn

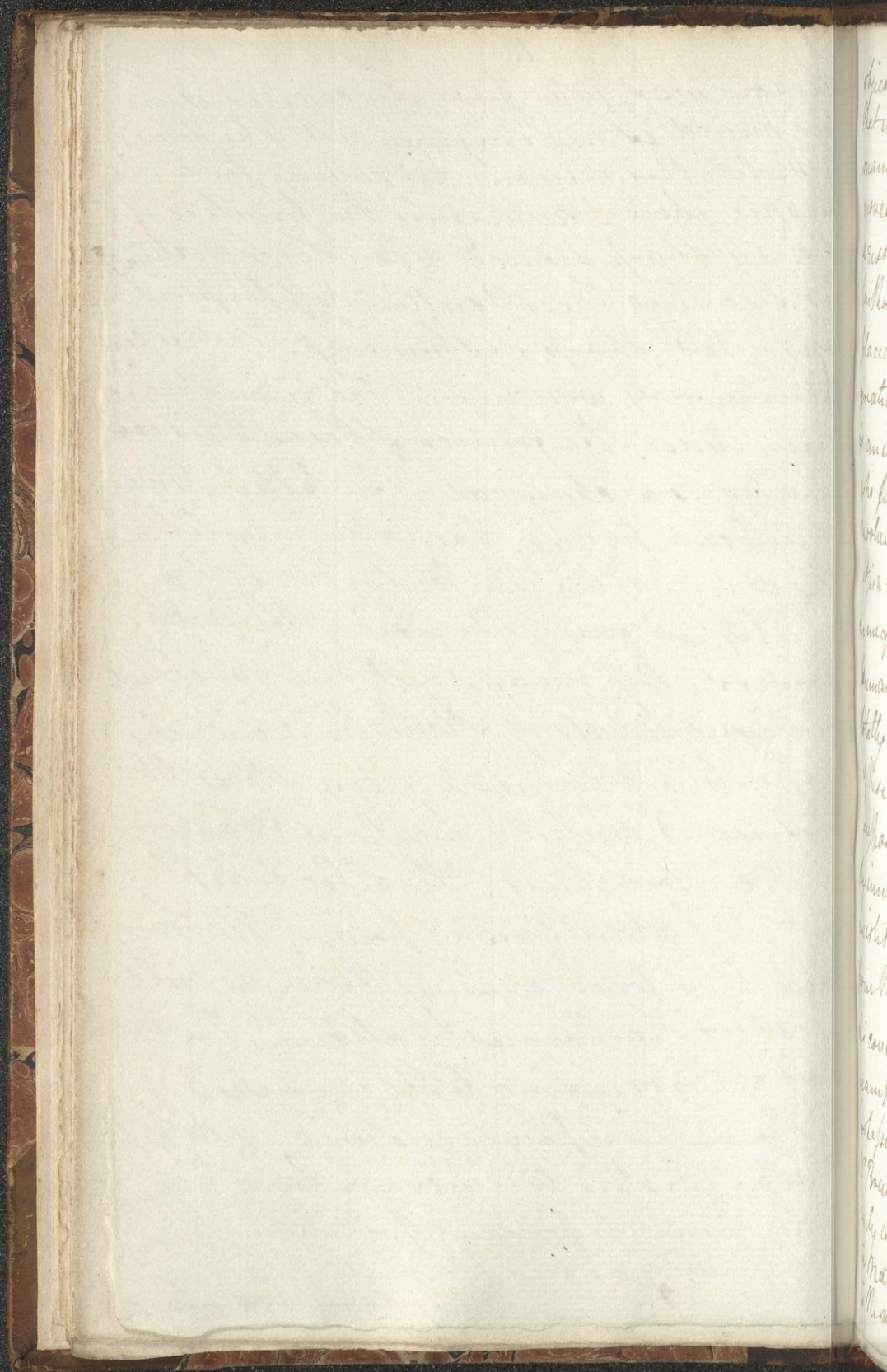


sometimes in small dynes what ¹²
Egypt & what Greece formerly were.
In all Countries Art has proceeded
since first from the common practice
of life spring most inventions thence
followed Science and soon the different
branches of Natural Philosophy as Motion
Hydrostatics Astronomy &c

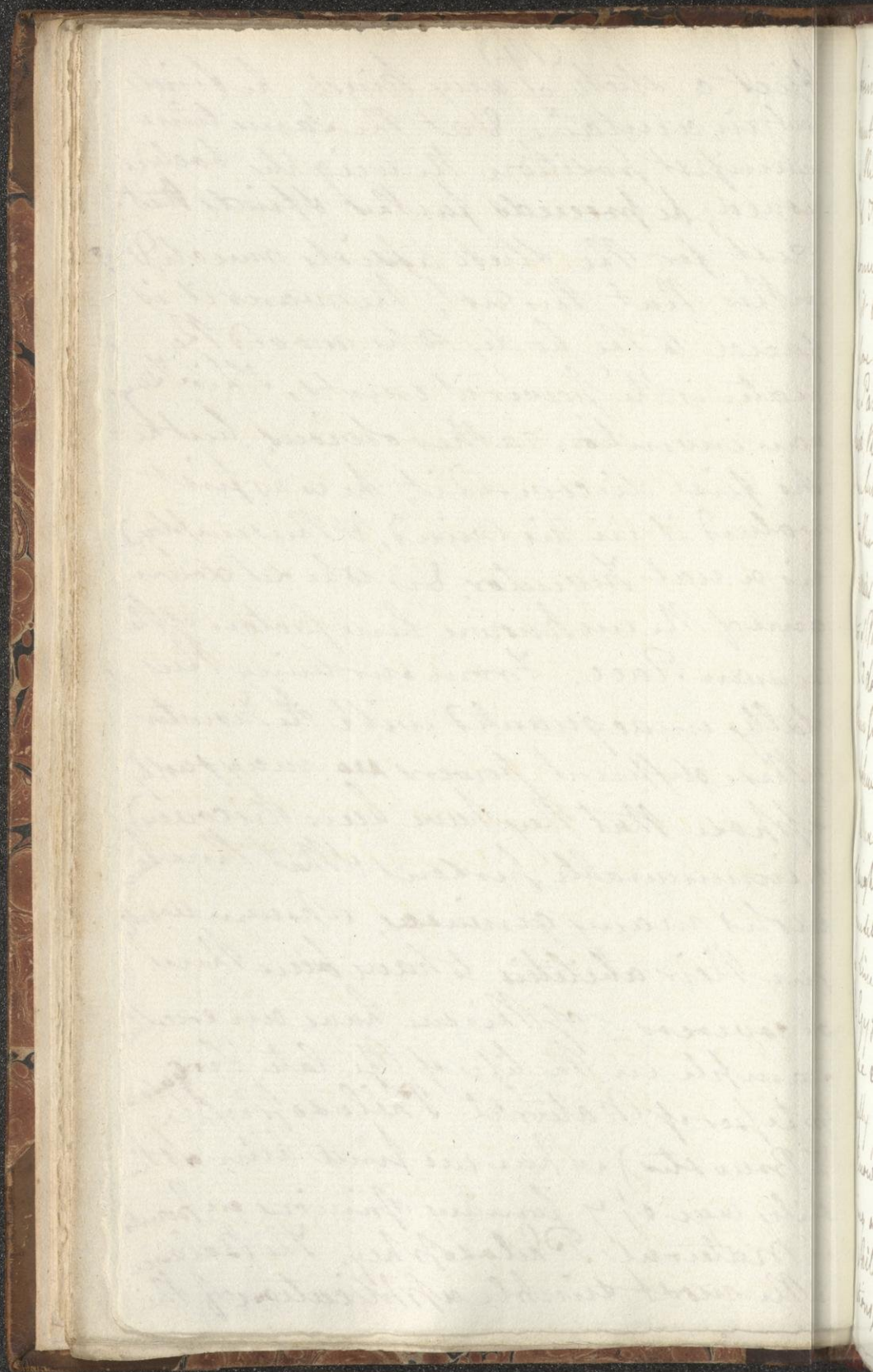
In viewing the weak steps of
Man we first find them employed
in acquiring a knowledge of what
may tend to render life more com-
fortable & happy thus among the
Inhabitants of New Holland many
very curious practices were found.
Of these we have a good example
in their art of kindling a fire by
rubbing one piece of wood against
another which shows to what de-
grees they must have arrived
before they could with such facility
perform this operation. Now this
came to be discovered & how that able



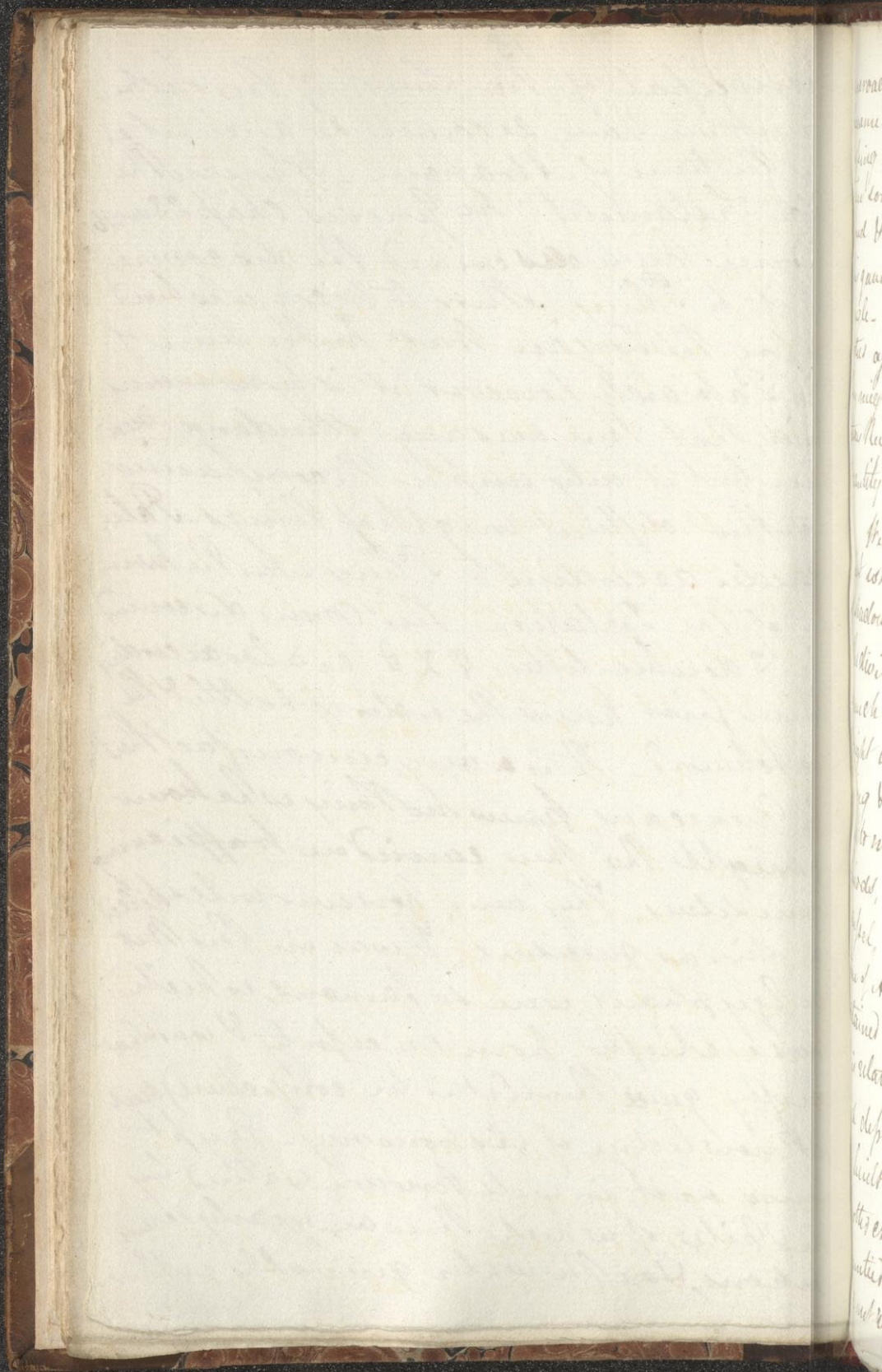
person was who first discovered it in
 his mind is an enigma not to be solved.
 Besides this curious discovery the same
 people were likewise in the practice of
 using sharp stones & other sharp natural
 for cleaving Trees & cutting off the fruit
 with this sharp instrument. This is cer-
 tain a very wonderful tho' more obvious
 invention. The former of these 2 discov-
 eries is a chemical, the latter a me-
 chanical power. The latter is no less a
 discovery than the Melque of the
 chief if not one of the first of the Mech:
 powers. By means of it they gave point
 various kinds of stone particularly
 Sphurine & common green stone, &
 thus formed missile weapons & various
 other contrivances. The other simple
 but important Mech: power, the Saw,
 was also found among them, as well
 as other barbarous nations. The me-
 thod of proceeding to the invention of
 this ~~invention~~ power is obvious. When
 it was wished to remove a large heavy
 body from its present position, to move
 naturally occur to one in place of
 his hand to employ some instrument



object a stick of any kind, he finds
 that in a certain, & at the same time
 manifest position the weighty body is
 moved, he proceeds further & finds that
 a rest for the stick assists much, &
 further that this rest, the more it is
 placed to the body to be moved the
 greater is the power it exerts. This ¹⁶ is
 an invention rather obvious, but he
 who first discovered it, he who first
 resolved it in his mind, & thus employed
 it, is a real Inventor. It is to be let down
 as one of the unknown here factors of the
 Human Race. From our living thus it
 totally unacquainted with the Inventor
 of these different powers we may easily
 suppose that they have been discovered
 by innumerable persons, & that there have
 existed many geniuses, who were wronged
 from their abilities to have been their
 discoverers. Of this we have an excellent
 example in the life of the late Professor
 of Natural Philosophy, (Dr Brewster) when we find him at the
 early age of 7 forming opinions on points
 in Natural Philosophy. The balance
 is the most simple application of the



principal of the Levit. of this Father
 must we have accounts so ancient as
 in the time of Abraham - Where in the
 Old Testament in Genesis Chap 23. v. 16
 some have ~~dis~~cried the discovery
 of it to Pliny, thos to them who lived
 before the Trojan War. In the time of
 the Patriarch however it is known
 said that there was any standard mea-
 sure, but it only implies the comparing
 together different weights of things - Pale-
 medes according to Pliny was the inven-
 tor of the Balance, this man discovered
 the 3 double letters Q X O, as also according
 to him first knew the order of battle & the
 watchword - It is a very curious fact that
 the Mexicans knew nothing of the hour
 of weights tho' they carried on trafficking
 & murders. They were however well skilled
 in linear measure. It was in this part
 the Egyptians were so famous, which
 arose chiefly from necessity & was what
 chiefly gave them (it is by conjecture) such
 a knowledge of Astronomy - Egypt
 being as it is well known watered by
 the Nile of which there are yearly inun-
 dations, & as the water gradually either

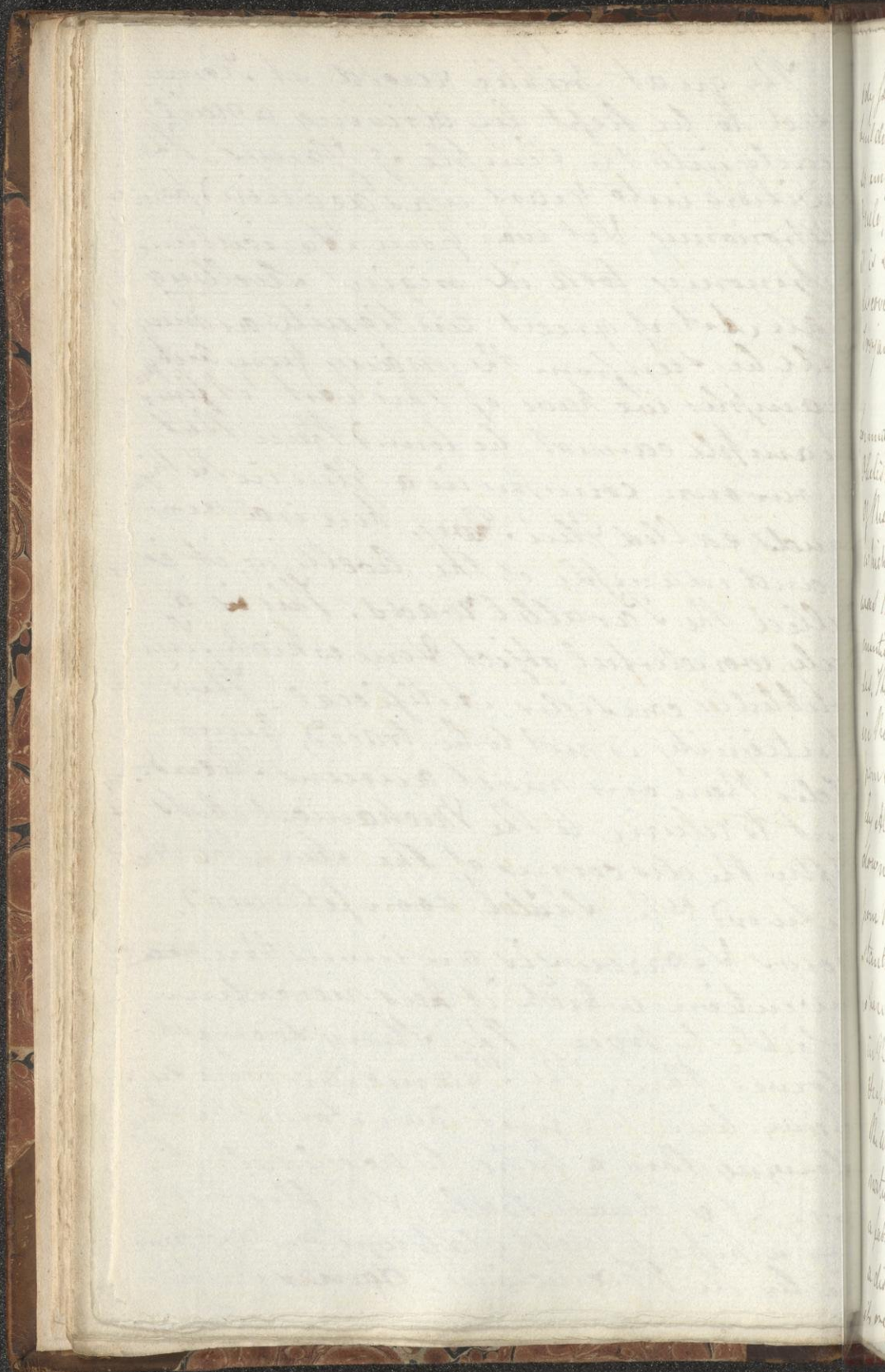


encroaches on, or incloses the land it became necessary for the farmers of adjoining lands upon the river to ascertain some method of calculating this land & thus knowing this yearly rent, this gave rise to the right angle, plane triangle - The cause however which Hypo- clitus assigns to this discovery is that they might ascertain what is ~~the~~ the taxes they had to pay from the exact quantity of this land -

We are told that Thales was the first who taught the Egyptians by means of shadows to measure the Pyramids - The division of time was an invention of much later date. The division of day & night was always obvious from the rising & setting of the sun. The ancients used to measure this day & into days periods, by the running of water out of a vessel, called a Clepsidron. In the time of Alfred the Great it was often ascertained by the burning of a candle. It is related of Darius, that when he had departed leaving a Bridge to be built by his return, he gave a knotted chord, one of which knots was to be untied every day, & if at the end he did not return they were to depart -

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The great public record at Rome
 used to be kept by driving a nail
 yearly into the Temple of Janus. The
 division into years was acquired from
 Astronomy, but war from Agriculture
 & honours took its origin. Leveling
 is an art of great antiquity as may
 well be seen from the many very antique
 examples we have of this art. A finer
 example cannot be found than that
 in our own country in a Glen in the high
 lands called Glen. Roe, here is a very
 grand example of the leveling, it is
 called the Parallel roads. This is a
 truly wonderful object & one which I must
 doubtless consider artificial. This
 antiquity is not to be traced, being
 older than our most ancient Records.
 But to return to the Mechanical Arts.
 After the discovery of the Gun, the Gun
 Powder & the Shovel soon followed.
 Bows & Arrows is an invention ~~ancient~~
 invention which it has never been
 possible to trace. The String & bow
 - lowered this. The Phœnicians are said
 to have been the first inventors of the Gun.
 Blowing thro' a pipe to accelerate the
 force of a small Ball, the blowing
 thro' a pipe to melt glass, was an art prac-
 ticed by the Phœnicians. Homer in his



only say informs us that they put in building his Ship in the Island of Calypso employed the Wedge, Plane, Winchle &c. but never mentions the Saw tho' it is said that that Instrument was discovered by Daedalus previous to the Trojan War.

Among the most wonderful permanences of Art must be ranked the Obelisks to be met with in Asia & Egypt. Of these Diodorus Siculus mentions one which was in Asia the height of which was 120 the base 25 feet square. He also mentions one called the Obelisk of Ramesses. This was cut out of the Granite quarries in the borders of Egypt, & was preserved from being destroyed in a general pillage by Alcibiades it was afterwards conveyed down the Nile to Alexandria & was removed from thence on Ship board to Rome by Constantine but was overthrown in the ruins where it stood, in a general disturbance in the City. It was again however repaired & replaced by Pope Sixtus V. on its stand. No wonder & admiration of all. It may naturally be enquired how so stupendous a fabric was ever conveyed from so vast a distance, or indeed ever moved from its original situation. Whence by means

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of the Wedge & Lever one end of the enormous pile is raised, suppose 2 ft from the ground by placing a beam ^{across} under the middle as possible, when the height perhaps is only a foot. The pile is thus almost balanced on the beam & by the least power may be moved on each side in this position a foot from the ground. The mass is firmly placed then again by the same process raised to any height suppose for instance 20 ft. The earth then or other material, that supports it on one ^{at one side} ~~side~~ ^{the} pile is thus set in an upright & erect position. This is the process by which when overthrown it was again raised.

Let us now take a ^{very} theoretical knowledge of the Greeks in Mechanics. Like travellers we find them exploring the various difficult part of the track without knowing what its nature or principles - The common opinions to which they were daily accustomed were their only standard & to depart from this was difficult as well as dangerous.

Thus there was to be perceived a number of phenomena in nature which from their regularity were termed

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first principles or Laws of Nature. Soon after it came to be perceived that there are in Nature 4 great Kingdoms or Elements which constitute the principles in nature. Which enter into most of its subjects. These were what is now generally termed the four Elements Earth, Water, Air & Fire. In every part of Creation there was to be seen arranged & blended into one another in a greater or less degree.

They were still carried farther in this course of discovery. By a little more attention they were taught that besides this general property each had apart its own peculiar properties & Qualities. They soon found that out of the 4 two Earth & Water were heavy, while the Air & Fire were light. The next qualities that came to be discovered were those of Heat & Cold, Dryness & Moisture. From the various combinations of these 6 Qualities we may derive most of the ancient Systems of Physics. It was from them that Empedocles derived his explanations of the various Phenomena of Nature. The magnificence & Splendor of the heavenly bodies soon drew the attention of Mankind.

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The grandeur of its appearance, its regular
 & successive revolutions to a spectator
 placed as it were in the centre, the regularity
 of the motion of some stars about the
 Polar points soon became objects of
 the most sublime contemplations, all
 this tended to give rise to those whims
 long since happily abolished, of Con-
 stantine robes, fiery matter &c. The
 system of Empedocles proposes one
 feature which is common to all the
 ancient systems whatever. I mean that
 in it all the facts are taken from common
 & every day remarks there is no such thing
 as experiment. After such premises the
 ancients next proceeded to explain &
 consider the Laws of Motion, a property
 which all agreed was common to material
 bodies - This was considered & defined by
 Aristotle, though it was also defined a
 considerable time before by Pythagoras
 who called it by the different appellations
 of "what is not"; "what is possessed of motion
change" &c. which are terms most obscure.
 Aristotle gave much of his attention to
 this subject, & defines it still more obscurely,
 than the former, he defines it as "Actus
entis in potentia" or as Locke expresses

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it the act of being in power. This Locke justly censures tho' in rather harsh terms he considers it "a jargon of absurdity". Besides disclaiming violently ag^t his many commentators. One of the names has been no less absurd in his ideas as well as definitions of motion. It was Epicurus who first gave a direct definition of motion the same as is now generally received. He defined it as "a continual change of place". But why so much on definitions of motion both in ancient & modern times? we are not to be led by a definition to a know ledge of its laws. Were Aristotle now alive I have not the least doubt he would readily acquiesce in the enlightened philosophy of Bacon & Newton, & put to shame all his numerous scolded commentators.

It is a principle in nature that a body once set in motion will continue to retain that motion till stopped by some extraneous circumstances. By Aristotle's honour all bodies after being put in motion have a tendency to stop from the undulations with which they are surrounded becoming gradually weaker till at last the body ceases to move. This as may be seen is contrary to the truth as established

in modern times. That the vis inertiae of bodies however now known should not have been obvious to them is not to be wondered at. They were wholly in the dark as to attraction, friction, resistance of air &c which gradually weakens the utilitarian motion of bodies. Thus if we roll a ball along the ground, were it not for these causes it would move on to infinity without stopping. How a body would move if these external causes were removed was a question which never occurred to them.

They divided motion into Natural & Violent. Natural motion was the motion of the heavenly bodies about the Sun, the Earth about its own axis &c Violent motion however was that caused by some common impulse or as they then called by Rectilinear motion. The true notion of motion was not acquired till the discovery of Copernicus forced on man. From this period we may date our knowledge of the celestial motions or motions in general. Aristotle maintained that the velocity of a body in motion was inversely as the medium density of the air through which it passed. This might at first sight appear an ingenious remark but a little nearer inspection shows us its gross error. If such

were really so, what we may ask would happen in a vacuum. Here according to his hypothesis motion would be incircumable or infinitely great which is impossible. In Philosophizing Men are always very apt to fill up the picture which they have framed with their own wide imaginations. This however cannot be the case in Mechanics in many of the Sciences however it is very common. Far more so than in Geology in which all the errors of hypothesis & fiction still remain.

In Mechanics many of the ancients are renowned & none more so than the celebrated Archimedes. And from him he first came to apply Mathematics to natural philosophy. He like all the ancient writers made no use of demonstration tho' he was not unacquainted with that method of discovering but reasoned entirely *a priori*. He only made great use of Geometry & assumed that in the lever a power in which he wrote well, if equal powers be employed at the ends of the bar the attraction is equal & in the cube it will therefore be balanced there, with a hook of the cylinder were all the

was pursued. Archimedes may justly be
 deemed the father of Mechanical Philosophy.
 From the discovery he made that bodies
 become lighter when immersed in water was
 formed this whole Theory of floating bodies.
 The many noble exploits which he performed
 at Syracuse tho' in some respects exagger-
 ated are nevertheless proofs of his amazing
 knowledge in Mechanics, particularly in
 what he performed by Mirrors. These by
 being properly placed had the most won-
 derful effects. In modern times Buffon tho' not
 unacquainted of the manner in which he
 performed these did also by the aid of Mirrors
 which all worked on hinges &c. by contracting
 & concentrating their power in one point
 produced effects similar in power to those
 of Archimedes as related to us.

There were lately discovered a Greek Manu-
 script by Anthymius in which he describes
 plans exactly after the manner of Buffon
 the manner in which these Mirrors were
 he used tho' he was also unacquainted
 with the precise manner of Archimedes.
 After Anthymius, Pappus added much
 to general knowledge by some wonderful
 properties which he discovered of the centre
 of gravity. Seneca also made many discoveries
 in Mechanics. He first observed that ships
 upon a River drew more water than when

at sea. This however did not suggest to him
the idea of the difference in the specific gra-
vity of salt & fresh water. He accounted
for it in a most extraordinary manner
owing to the difference of depths. Thus there
were not among the ancients any regular
system of Tides.

Plutarch first discovered that the
orb of the Moon was an opaque substance
that the light with which she shines is
borrowed from the Sun. After him De-
mocritus discovered that those spots
as to be observed on the Moons surface are
all inequalities which is a very wonderful
approximation to the true system. The famous
of these able men supposed also that the
reason of the Moons regular rotation &
her not falling to the Earth, was owing to her
rapid motion, like that of a sling. It was
Democritus who first discovered that the
Milky way was an assemblage of stars,
this even without the aid of a Telescope.
Since also long after the time of De-
mocritus was also a great astron-
omer & made some useful discoveries &
observations, which proved very useful
to those who followed him; it were to
astronomy he chiefly directed his attention
consequently in which he excelled

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— and particularly about Cornets of which
he predicted many things which in Mo-
dern times have been found in general
to have been the case

In those times certainly some
brilliant discoveries were made but
they were but few & seldom. Truth &
Falsehood met equally together & some-
times the one & sometimes the other, but
more commonly the latter prevailed,
and was the occasion of those many
errors & obscurities which are too prevalent
in the Ancient writings. We really ought
to beware of those vain panegiries which
have been too lavished by some on All
Ancient Knowledge. The truth is
there are certainly to be found many
shining passages among them which
do ample credit to the Authors, but
properly speaking the Language of
panegyric thus profusely bestowed on
them should be converted into that of
apology. Let us remember that the
Eye of the World, is as Bacon says
"every Day erring". We are not to
suppose that Science or Art could be in
perfection in its very Infancy for so it
was among the Greeks: but must pro-
ceed by gradual steps to that height.

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What sensible Man cannot help being astonished when he hears one of our Modern Savants, one who lives in so enlightened an Age come forward & assert that all the discoveries of Modern times from the meanest to the most sublime were known to the Ancients tho' lost in the dark ages. Let us take for instance one of their discoveries, I mean the origin of Springs & fountains, in which we shall see not only the absurdity of the assertion but also the ignorance of the Man who makes it.

Dutertius one of those extraordinary admirers of Antiquity, asserts, among many other assertions equally absurd that the origin of Springs was fully known to the Ancients. To satisfy ourselves let us look into the circumstances & see what really was their knowledge on this head. It was very generally supposed that they had their origin thro' subterraneous Canals &c which conveyed it through the Bowels of the Earth, in later times it has been discovered that they flowed from the Atmosphere, in Clouds, Mists, Rain, Evaporation &c as you all know, now no different are the two opinions, which

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is a very plain proof that it is not only
a Modern discovery but also of the
ignorance of the Author either in the
modern or ancient Matter of fact which
had he known he certainly would not
have made so gross an Assertion. Of
this there are also innumerable other
examples sufficient to silence these
writers. If you really would wish to
have a fair and impartial account
of the Knowledge of the Ancients in Phy-
sics, an account which will be bestow
on them too great or too slight encomiums
you may consult the writings of Gas-
sendi, who was a most able Man &
who has most justly been styled the
most learned of Philosophers & the
most philosophical of the Learned.

If you would wish to read an able
work on the commentaries ^{of Aristotle} you may
apply to the "Analysis of Aristotle" by
Dr Gillies in which you will find their
writings most justly treated.

Fastidiousness is the great Pee-
ture of Ancient Physiology. The idea of
Galileo watching for hours the flame of
a Candle, or measuring with such ex-
actness the velocity of a Body falling
to the Earth would have been
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decided in their times. Hypothesis was
 their great tool, experience they never
 attempted, it in no instance cast its
 faint rays on Science; Conjecture
 was filled up by the imagination which
 in some was (as may be conceived) most
 lively. From all this I draw the con-
 clusions than that there is nothing
 more truly absurd than those unmea-
 sured encomiums bestowed by some
 on Antiquity. There are I allow to be
 found among them many fine pas-
 sages which reflect on the Author the
 highest credit, but that all modern
 discoveries should have been known
 in Ancient times, and other such asser-
 tions are encomiums in which I never
 can agree notwithstanding my due
 reverence for the knowledge of Antiquity;
 and must conclude with Bacon ~~insay~~
 ing that it is in the light of Modern
 times not in the darkness of Antiquity
 that we are to find the discoveries of
 Science.

It was about the end of
 the 16th Century that the renowned
 Lord Francis Bacon, the Author first
 now quoted, appeared before the world,
 than whom it perhaps has never ~~no~~
 = ~~decided~~

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a greater. He was a Native of Britain
and was the first who discovered any
regular Method of proceeding in discovery.
He commenced by drawing his distinction
between the Sciences & the Arts.
He shewed that there can be no real
discovery from Theoretical views alone
but practice & experiment is the great
source of all discovery whatever, & that
facts not bare opinions are to guide us.
He shewed that the way was slow
is, but sure & steady which he proposed
to follow. By slow & gradual steps we
are to ascend from Species to Genus &c
but that patience & perseverance
will gradually bring to discovery that
which is true, which cannot be mixt
up with any of the vain and absurd
fictions of the Ancients, but with solid
evident truth. He proceeded by ex-
cluding every thing whatever which
was not necessary for accounting for
the phenomena. This great work was
his celebrated "Novum Organum".
In this he points out the various fall-
acies in the Nature of Man which
are the great causes of error. This he
divided as you know into 4 kinds
or Idols as he termed them, because

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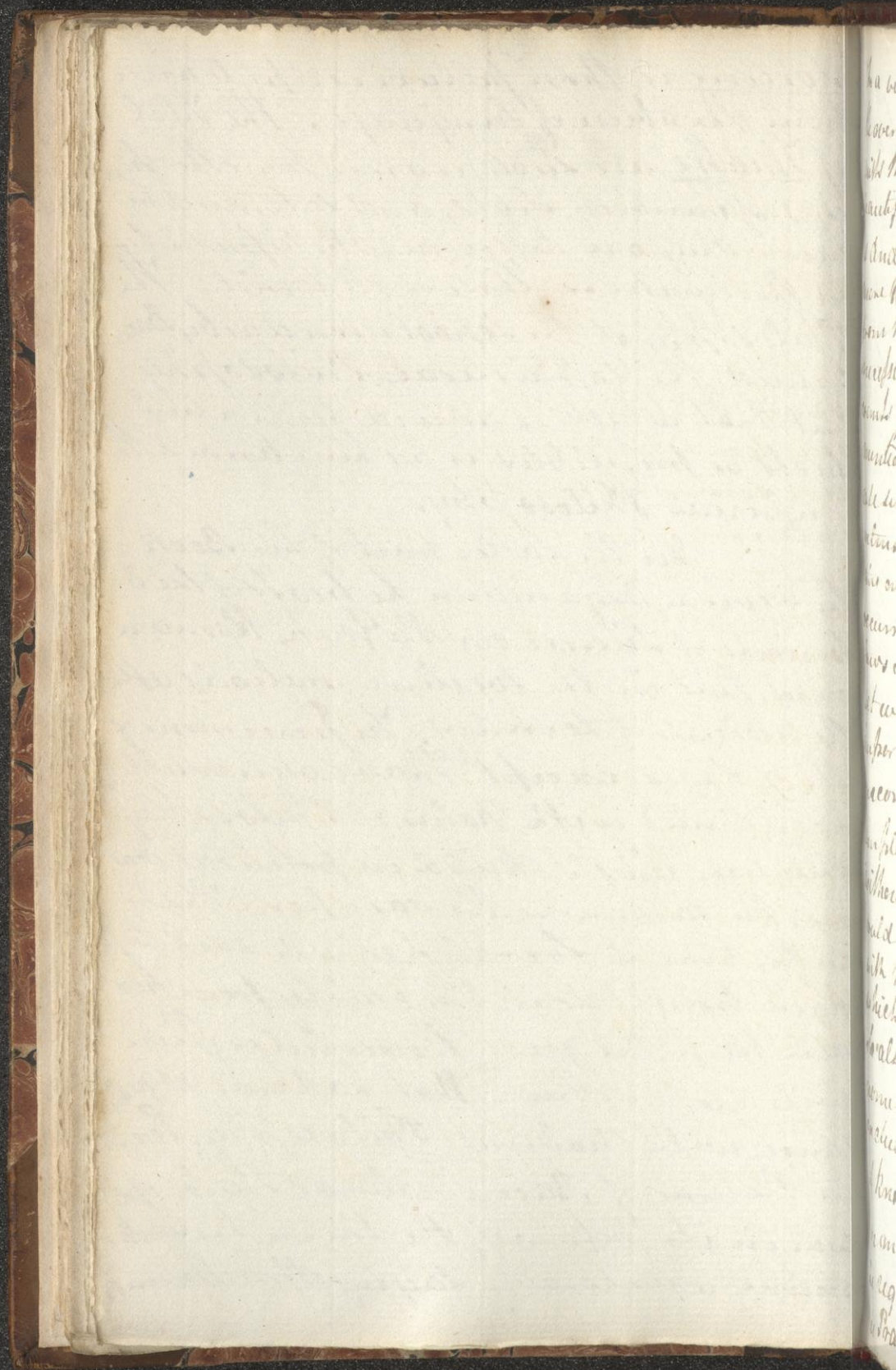
they are so frequently the veneration
 of Mankind. They were the Idols of
 the Tribes, the Gen, the Forum the
Theatre, according to him Idola
Tribus, Speies, Fori, & Theatri. The
 Idols of the Tribes were those fallacies
 and errors apt to fall into from what
 is common to all Mankind. Of
 these the chief is that tendency to
 common with us viz. to render objects
 & operations in the material world
 more uniform than they really are.
 Thus for instance because it was
 observed that the heavenly bodies
 moved round the Sun, it was long
 supposed that their Orbits were cir-
 cles, which have since been found to
 be Ellipses. So also the Earth was for-
 mally considered a sphere tho' it was
 afterwards found to be a kind of
 spheroid. The Idols of the Gen. the
 prejudices of this class arise either
 from more mental than bodily consti-
 tutions or from tendencies produced from
 education. Hence the great influence
 the mind has in some men over the
 body, as also the particularities in
 the constitution of some. The 3^d Idol
 or that termed

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Forum is those fallacies apt to arise from the abuse of language. The Idol of Theatre are such as arise from the opinions of various sects, and so termed because they are so frequently represented on the Theatre or Stage of the world. The Philosophy of the Schoolmen was by Bacon termed the Sophistical Philosophy but that which is derived from a few facts or principles is by him termed the Imperial Philosophy.

In the latter part of his Book the Novum Organum he treats of the 3 periods of Science over the Greek, Roman, and that in the western nations after the revival of Learning. In Greece none of the 7 Sages except Thales were much acquainted with Natural Philosophy they were chiefly skilled in political matters, the same was the case from Thales to the time of Socrates (who is said to have brought down Philosophy from heaven from his great knowledge) There were none of them that had any acquaintance with Natural Philosophy. Even in the time of Bacon Natural Philosophy was in its Infancy, He has in his works many memorable sayings & Meditations.



In a very beautiful passage he predicts, the overthrow of the system of Meléche, with their so prevalent. In many other beautiful passages he shows that there is and will be in modern times, much more know than in ancient and that from the increase of age it is absolutely necessary that there should be. He accounts for this in many other ways but mentions particularly that such is the case since the Ancients in all their extensive enquiries made no observations on the common and ordinary occurrences every day presented. Those laws of the material world which act every day before our eyes are more important to be known than other more uncommon; as in the familiar example of a stone falling to the ground, without the observation of which we could not have been made acquainted with the motion of the celestial bodies, & which prevented them knowing such. So also if we ^{do not} observe the common phenomena of Air & Water we should be excluded from many extensive ranges of knowledge. In short as Bacon began we may conclude that something more is requisite than mere Theory, that is Practice & Experiment without which

X Bacon's 3 great divisions were 1st That which is subordinate, or things relating to Memory 2nd Fancy 3rd Reason. Under the 1st belongs all History belongs. The subjects belonging to the second is Poetry the fine arts &c. That which belongs to reason is Science. This division is not altogether accurate, but to a person like Bacon to whom science is indebted so much, slight faults and a degree of prolixity must be overlooked. We are at present particularly concerned with the first or Natural History. He divides history into 3 great heads I sacred history II Civil History which he divides into 2, 1st Ancient 2nd Modern III Natural history which he divides into three 1st Regular course of Nature 2nd The irregularities of Nature 3rd The History of the use of Nature or History of the Arts 1st with regard to the regular course of Nature - This includes the Hist. of the Surface of the Earth, Geography, Geology, History of Mountains Rivers &c. Then comes the History of the interior of the Earth, or Mineral Kingdom. Next you have the history of the Atmosphere next the history of Animals, this you see belongs to natural history and is included in the 1st division, 2nd The Irregularities, These must not be altogether left out but with regard to them a rigorous enumeration is necessary

few real & lasting discoveries can be made. x

Let us next proceed to the consideration of the Rules by which our Philosophical enquiries should be regulated. And the 1st which I shall mention is that Facts that are true should be distinctly related, that such as are authentic should be carefully remembered and that such as are doubtful should be by no means neglected but marked down. Hence born not observing this rule credibility becomes frequently to be considered as the object of ignorance. I would also 2nd recommend that the language be simple, and particularly observe say's Bacon the 3 great points viz Accuracy, truth, & perspicuity. 3rd Remember that you do not introduce Theory into Facts. This is a rule that ought particularly to be attended to. For as we pass so rapidly from Imagination to Reality we are very apt to be led astray. In Botany this mode of Theory abounds; in Mineralogy it is very frequent & particularly in that branch of it termed Geology when it is in a very great degree.

By the word Form which

Earthquakes, Meteors, Stones &c are in-
cluded under this head, for as to the
latter there can be no doubt but that
they were formed in the Atmosphere both
from their composition, & the situation
being always the same. 3^d The history of
the Arts; you must not wonder to see
this ranked & forming one of the divisions
of Nature. Man in no case by the Arts
does more than bring together materials
which in Nature are separate, so that
properly speaking it is Nature acting.
Gunpowder is a good example of
this, it is by the bringing together of
substances that it is formed; and what
does Man do towards the explosion?
nothing but applying the light.

|| Herodotus when speaking of the circum-
navigation of Africa, admits of the pos-
sibility; and when the traveller told
him he found his shadow changed
always falling to the South, Herodotus
was amazed and would not believe it.
Pliny has very beautifully expressed
the credulity arising from ignorance
"the force and magnificence of Nature"
"will never be believed if Man confines
himself to parts & does not embrace the
whole" || See next leaf

X There are perhaps entitled to come

Bacon mentions not infrequently is meant not those substantial forms which are ascribed to Aristotle, but the actual being of any substance, what it really is as in examples of transparency. Indeed Bacon was frequently at a loss for words in his *Philosophy*. His proofs of the deduction are worth your attention; and from his *Novum Organum* you may reap much advantage. There will be found his 27 instances or experiments which I now intend in some case to go over. Of these the first place is given by all, to those instances termed Ist Instance Solitaria in which none exist but in its essential or solitary form; as in crystals, cutery stals, dew drops. They are not all ⁱⁿ common with cloth &c. Hence the form of a colour which is not a quality in Bodin, & hence Newton discovered the decomposition of light. The next we mention are IInd Instance Migrantes These are substances in every respect the same except in one, & hence it differs from the ~~other~~ which is altogether different except in one. There also the fluid is denser than in the other. The next is IIIrd Instance ostensa such as are frequent & predominant instances

first. This is when a substance which
has ~~its~~ ^{its} nature but becomes ~~so~~ ^{changed} afterwards
for instance Glass which is transparent
but when powdered becomes opaque;
so that homogeneity contributes to
transparency, & porousness to opacity;
a piece of dry paper is opaque but moisten
it with water or oil and it becomes in
a certain degree transparent. Suppose
we enquire into the cause of fluidity.
When heat is withdrawn from water
it becomes solid; if you take Quicksilver
you will have the same result, here again
is merely the abstraction of heat, so that
heat may be supposed to be the cause
of fluidity; you must give it the latent
heat as it is termed or otherwise the flu-
idity will not be regained.

|| Instantia ostensiva let us suppose
the question, is the air heavy or light?
This was for a long time decided on the
wrong side; but let us view the case in
a different manner to what the Ancients
did, let us abstract it from experiment
and apply it to another, and let us find
then some Instrument to discover whether
it has weight, and we are indebted to
Torricelli for our admirable Instrument
X Turn over—

in the Atmosphere. If for instance we were to enquire about the form of the Land under the Sea, the many Corals which line the coasts &c. The next is "Instance Analogous" Such as in the Telescope, Microscope in Art and in Nature a persons Eyes, between which there is a great analogy. The Tools and long branches of a Tree become very similar. So also the great analogy which exists between the wings of a Bird and the Fins of a Fish. Also it is exemplified in the Analogy of Echoes & the vibrations of the ear.

Bacon himself forms an Analogy between the Gum on certain Trees and the Gums embedded in various Minerals, both of which he supposed to be the same as it were of the Body. This however is erroneous and great caution should be taken in forming such analogies. The 5 Experiments or instances is "Instance Singular" There are examples that are singularly remarkable among others, as in the case of the Sun among the other Stars which are contained in the System. So also among Quadrupeds the Elephant is a singular instance. And by Bacon among the Arts the invention of Paper is singular.

for the purpose, the Barometer. The
Air pump leads to the same conclu-
sions, by weighing a Bottle full of
air and then empty.

x Instantia analogæ or conformis
Whin Stone & Laven is a fine example
of this. This same Whin can be repro-
duced in our crucibles. As that which
we can by art produce similar to that
in Nature comes under this Instance

Many other instances might be mentioned as in the case of Saturn and the ring with which it is surrounded. Also the singular properties of the 4 key constellations. The Stones also which frequently fall from the atmosphere are singular phenomena, as are also the various phenomena & peculiarities which attend many of the animal kingdom. They are singular & uncommon hence sometimes denominated Monogamous.

Having proceeded to the selection of some of the experiments recounted by Lord Bacon in his *Novum Organum* I now consider the next of these experiments of *Justanus* on *VIth "Instance Crucis" Experiments* of the Cross. Here there are supposed to be 2 or 3 causes and of these we are to choose the best. It has the appellation of the Cross assigned it by Bacon because it is supposed to be a cross or finger post to direct the traveller on his way. Thus in the two systems the Ptolemaic & Copernican there might at first be some doubt which was right but the great simplicity of the latter rather is apt to give it the principle preference.

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The help of the telescope by its observations would afterwards ascertain this. Another example of this may be obtained from chemistry. It is that also are always heavier by calcination. For it is a question whether bodies when calcined lose or gain weight. The wonderful enquiry of Lord Bacon whether all bodies are kept right by the attraction of the centre of the Earth or by the adhesion of their separate particles is certainly a remarkable enquiry for a time when Science was in so rude a state. The next kind of experiment of Galton is as they are termed is

VIIth Instantia Lampadis Experiment of the Lamp, there are such as are known to us by the means of our senses. As also

VIIIth Instantia Januae Experiment of the gate, which are those which we discover by the sense of sight.

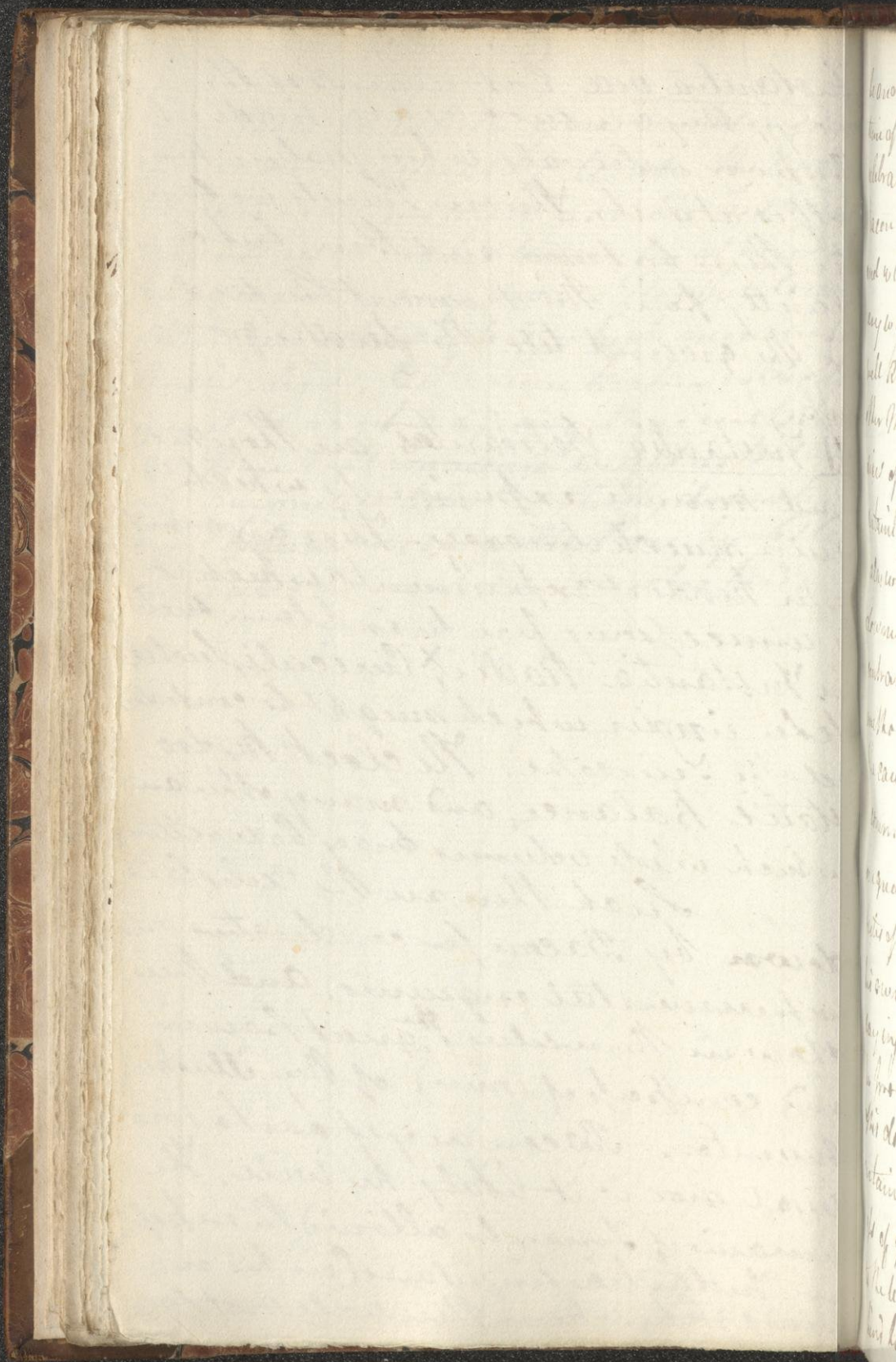
IXth Instantia Titantes There are such as enable us by certain means to discover, what are of themselves insensible such as the weight of air manifested by the air pump. The next is

x Or those by which you measure of
measures accurately. Under this I add
Bacon enumerated all the Instru-
ments used in his time, but of course
may add many more, The whole Astro-
nomical apparatus, which measure
angles, lines, &c. The time keeps which
must be ranked among these instruments.
2^d Now that measure weight as Balances
the Barometer tube &c. The Hydrometer
and Photometer especially those by Leslie
may also be ranked under this kind.

Instantia via Experiments of the way, they are such as are made at leaps or intervals when Nature herself is at rest. Thus in Plants we can see them but now and then, but constantly from the moment the seed is in the ground till the plant is grown up.

Instantia Delicantes are those more and more minute experiments which require much delicacy. There are many other kinds of experiments which it is unnecessary here to explain such as Instantia Radii, Curiculi, Luctae, &c. under which might be considered the Telescope, the clock hydrostatic balance, and many others in which whole volumes may be written.

Such then are the rules laid down by Bacon for conducting our experimental enquiries. And they show in themselves ^{the} great power and compass of mind of this illustrious Inventor. Bacon as yet has had no rival nor is it likely he will. He remains if I may be allowed the expression an Instantia singularis (in his own words) like whom there will not soon



be another. About 40 years after the
 time of Bacon lived Descartes another
 celebrated Philosopher. Both he and
 Bacon set out with the same principles
 and with the same end in view, but how
 very widely they differed in that end is
 well known to all. Descartes was like the
 other men far above the foolish preju-
 dices of his times. He was a man of
 certainly very high abilities, tho' these
 alas were misapplied. He reasoned
 downwards from causes to their effects
 contrary to the common & proper
 method of reasoning from ^{effects} causes to
 the cause that produced them. He
 commenced his philosophy with
 one great cause, the existence & attri-
 butes of the Deity. After this he proved
 his own existence by the well known
 saying "Cogito ergo Sum". after which
 he proceeded to prove other things.
 His doctrinal thought on the whole
 certainly very erroneous was nevertheless
 of great benefit in many respects
 to the world. Descartes has left be-
 hind him none who did none ^{ser-}
 vices

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to the different Sciences of Optics & pure Mathematics. He was certainly an excellent Geometer and will ever be so among future ages. Another great man who lived much about the same time was Galileo whose great & superior talents will ever be heard of with reverence. He is frequently compared to Bacon, and was like him a true genius. The History of England at the conclusion of the reign of James 1st then is there given a remarkable comparison between these two great men, a comparison in which however I do not exactly agree, as he is by far too severe on Bacon. Galileo was a native of Florence. He made many most important discoveries and from the persecution of his things were prevented from making many others which might have been of his not advantage in after times. He as you know was the inventor of the Telescope one of the grandest inventions ever made by man. He also first hinted at the law of Attraction

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we have now pretty fully gone over the ~~various~~ rules laid down by Bacon for conducting experimental enquiries, Let us now consider how far these different rules have been observed in the discoveries that have since been made. The great point in all discoveries are the principles on which they must depend. In the mechanics after the laws of motion have been discovered the other parts soon follow from them as first principles. The definitions must be derived from experience. Thus it was from a few first principles the whole doctrine of fluids took their rise. Bacon himself reasons as much as possible in physics from mathematics as first principles. In that part of his works "de Augmentis" he seems to give hint at what Newton afterwards discovered. He remarks that it is the same power which keeps the moon in her place, which also effects a stone falling to the ground. But also it must be remarked that before this Identity can be said to take place

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we must know more precisely. The semi diameter of the Earth, the distance of the Moon from it, & also the first second of the stones falling must be accurately measured. Here there is complete example of the "Experimentum crucis". Newton at first failed in his attempt as the circumference of the Earth was not at that time precisely known, but when it was, he again resumed his experiments & found it exactly. All this is to be compared with the Theory of Gravitation. Another remarkable instance of this is in Optics when light from one enters another transparent body it is said to be refracted. Experiment is not alone sufficient here, Mathematics is brought in to our aid by means of which we discover some general laws or first principles. A complete application of Induction is not always necessary, nor is it always employed. Bacon's method of induction is only useful when the discovery is quite new, never before in the least degree known.

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That part of physical science which is to engage our attention tho' it is chiefly founded on Experiment yet the rigorous induction of Bacon is not always necessary. In Chemistry however in particular, Induction ought to be observed; and I doubt not but that the many variations which are continually taking place in that science are owing greatly to not observing sufficiently the rules of Inductive Reasoning.

Having now concluded this detail of Philosophical knowledge, I proceed to lay before you a plan of this course of Natural Philosophy.

Theory of Motion

Natural Philosophy may be said to be the consideration of the phenomenon of motion produced from a distance, or by forces acting at a distance in which there is a change but none in the constitution of the bodies employed. Thus there is the difference between Mechanical & Chemical philosophy. If for instance I knock a piece of Stone from off a large mass there is no change in the constitution and properties of the ~~Stone~~ ^{Stone}. If however I plunge a piece of Marble into an acid it is dissolved. The former is an example of Mechanical the latter of Chemical philosophy. The first part of the subject is about the Laws of Motion which is the action of large masses on one another. The first great branch of the course is termed therefore the Theory of Motion.

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The first thing ⁽⁴⁷⁾ then to be done
here is to abstract several substances
and only consider separate qua-
lities as the impenetrability of bodies.
All bodies are supposed of freedom
to obey the Laws of Motion & Gravity.
The Theory of Motion is thus then divi-
ded into 2 subdivisions 1st The motion
of free bodies which is termed Dyna-
mics. It is seldom that Bodies are
altogether free. The circumstances in
other cases differ & the bodies are con-
strained to move in a certain space
here then the body is not from any
thing free as is the case with the
extremity of the radius of a circle &c.
This then forms the 2^d division named
Mechanics which is the motion of
bodies under restraint. There are then
2 terms which it is hardly necessary
to mention, to which I do not refer either
in motion or at Rest, Motion to
express them in motion & Statics

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when a fluid of either kind requires
new modifications it is unequal
bodied Hydromanics which may
be different in different circumstances
tho it is either compressible or incompressible
as in the case of water & air.
When we consider it at rest
it is termed Hydrostatics when in
motion Hydrodynamics. When we consider
Air at rest it is called Aerostatics
when in motion Pneumatics from
πνευμα σπιντα.

We must proceed to consider
the celestial phenomena this considera-
tion ought properly to come after Dy-
namics this arrangement however
I will not here follow as we ought to
consider chiefly the mind of the learner
for where perhaps this would be
rather too rapid & difficult a step.
This then will now be ⁱⁿ produced Vis terminis
Physical Astronomy.

Then then concludes the Theory
of Motion & we must proceed to the
science of Optics. This is an insulated
science

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and only indeed useful on account
 of the wonderful discoveries of the Tele-
 scope which depends entirely on its
 principles. Then follow 4 other subjects
 which shall be considered at the con-
 clusion not being combined with any
 of the former. I mean Heat, Mag-
netism, Electricity & Galvanism

Such is the plan I intend pur-
 suing in the following Lectures
 which for their interest & utility
 will I hope compensate for any
 labour you may have to under-
 go. The utmost attention will
 be requisite in many parts without
 which it will be impossible to proceed
 with the attention I expect from you.
 I hope nothing in Lect will be want-
 ing to elucidate & explain the subject.

I now proceed to enumerate
 what part of Mathematics is
 requisite for this course of Natural
 Philosophy

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as also to mention the definitions of some terms I shall be obliged to use during the course.

You must I hope be aware of the vast utility of Mathematics in many branches of Science but particularly in that in which we are about to enter. By them alone are ascertained most of the general Laws of Nature — The Axioms of the Science are truths not to be found by experiment or in any other way to be demonstrated. They are truths which no one hears without immediate assent to their truth, thus no one would attempt to prove that things that are equal to the same thing are equal to one another, that the whole is greater than any one of its parts. But then the Elementary parts of Geometry should be thoroughly known. But here you must fully understand what I mean by Elementary. It is sufficient to say that they

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consist in the considerations of the pro-
 perties of straight lines and circles and
 also the properties which are generated
 from them many then is ranked the
Cone which is nearly formed from
 the revolution of a right angle on one
 of the sides adjacent to the right $\angle$
 also the the properties of the Cylinder
 which is deduced from Elementary
 principles being the revolution of a
 parallelogram on one of its sides. The
 consideration of the five Platonic bodies
 are also Elementary. If you would
 have a good book on the Geometry of
 Solids I would recommend Simpson's
 elements of Geometry which in the
 solid Geometry is even superior to Eu-
 -clid. There are also some French treat-
 ises particularly one which has gone
 thro' several editions and is very gene-
 rally diffused over the Continent, it is
 the Elements of Geometry by Legendre
 The book lately published by my
 colleague Mr Leslie is also much
 to be recommended particularly for its

Nicholsen's treatise of Natural Philosophy
or what is a better look Cavallo's Treatise
Philosophy. Introduction to Nat. Philos.
by Bridges, which however is chiefly con-
nected with Mechanics. Wood's Mechanics
Elements of Mechanical Phi: by Mr
Robertson This work tho' not finished is
still very valuable. Gregory's Mechanics
a treatise on Rotatory Motion, Ferguson's
Nat. Philos. edited by Brewster.

Geometrical Analysis. Much advantage may be derived from a knowledge of solid Geometry as laid down in 11 & 12 books of Simplicius Euclid. Also a knowledge of Plane Trigonometry will be of much advantage. A little knowledge of Algebra also will greatly conduce to this study; as far as simple quadratics, this is all the Algebra absolutely necessary, but more would be very useful. We must make ourselves completely master of the Algebraic language. We now pass to the higher Geometry. This is distinguished by its continual growing or change of its condition or as Sir Isaac Newton termed it its continual flowing. There are considered the Conic Sections which however some reckon elementary as they are only generated from an Elementary figure viz. the Cone. These are considered chiefly

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The properties of the Parabola & Ellipse
the former in Dynamics and the
latter in Physical Astronomy. On
the subject of Algebra I would recom-
mend Wood's Elements. The part of
Geometry called transcendental is by
no means that part which treats of
the Cycloid & Epicycloid. I would
also recommend to those who have
leisure & are fond of it to study Flux-
ions & particularly Simpson's. Except
Simpson, I would refer you to the Greek
& Roman writers, for tho' the discovery
of Fluxions was first made in Britain
by Sir Isaac Newton yet it is in Greece
~~we are to look for~~ Germany & Italy we
are to look for the best & most numerous
writings on the subject. Among the
best books must be ranked Lamé's
as also Euler which latter book is a
most excellent work on higher Geome-
try, Euler was a man of the profoundest
knowledge in Mathematics adding
to it a clearness and brevity

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in which he has undoubtedly remained
unrivalled. And I hesitate not to account
him one of the first Mathematicians
this world has produced.

I would wish to direct your
attention to the outlines of the heads
of the lectures I have published,
as I intend to use it as a kind of
text book and shall refer you to
those particular paragraphs which
I wish to impress more on your mind
and shall also endeavour to prove
what is there laid down by example.

Par. 1. Philosophy is in general a
knowledge of the general laws of Nature.
When it is considered in its most gen-
eral sense facts ungeneralized cannot
constitute Philosophy. That branch
as I have already remarked ^{to} which
treats of *Genus Species* &c. is termed
Natural History; this is the general term
but not in the acceptance Bacon
received it, who considered it as facts
of every kind.

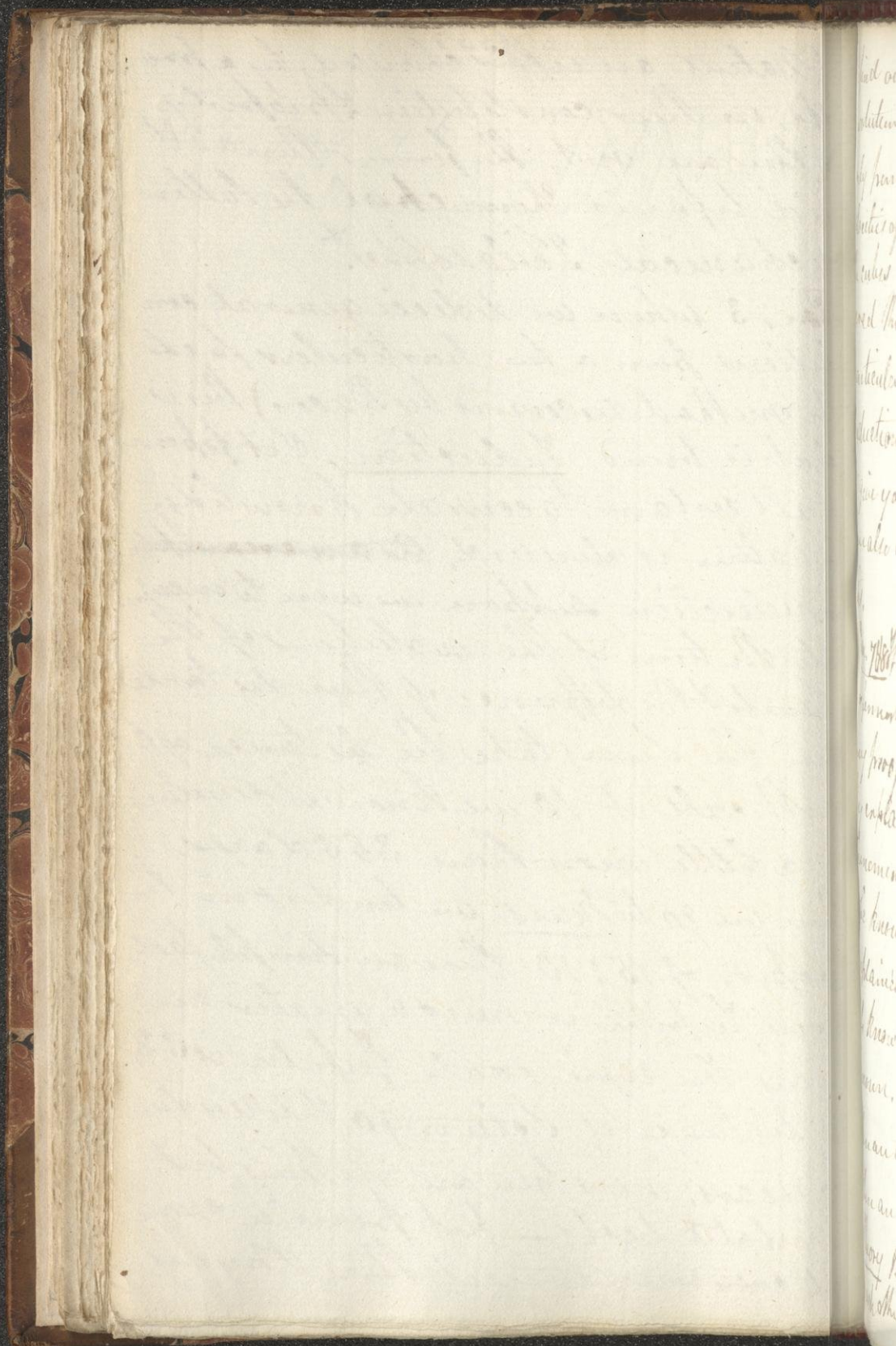
Par 2. Now the various circumstances

+ See page 46

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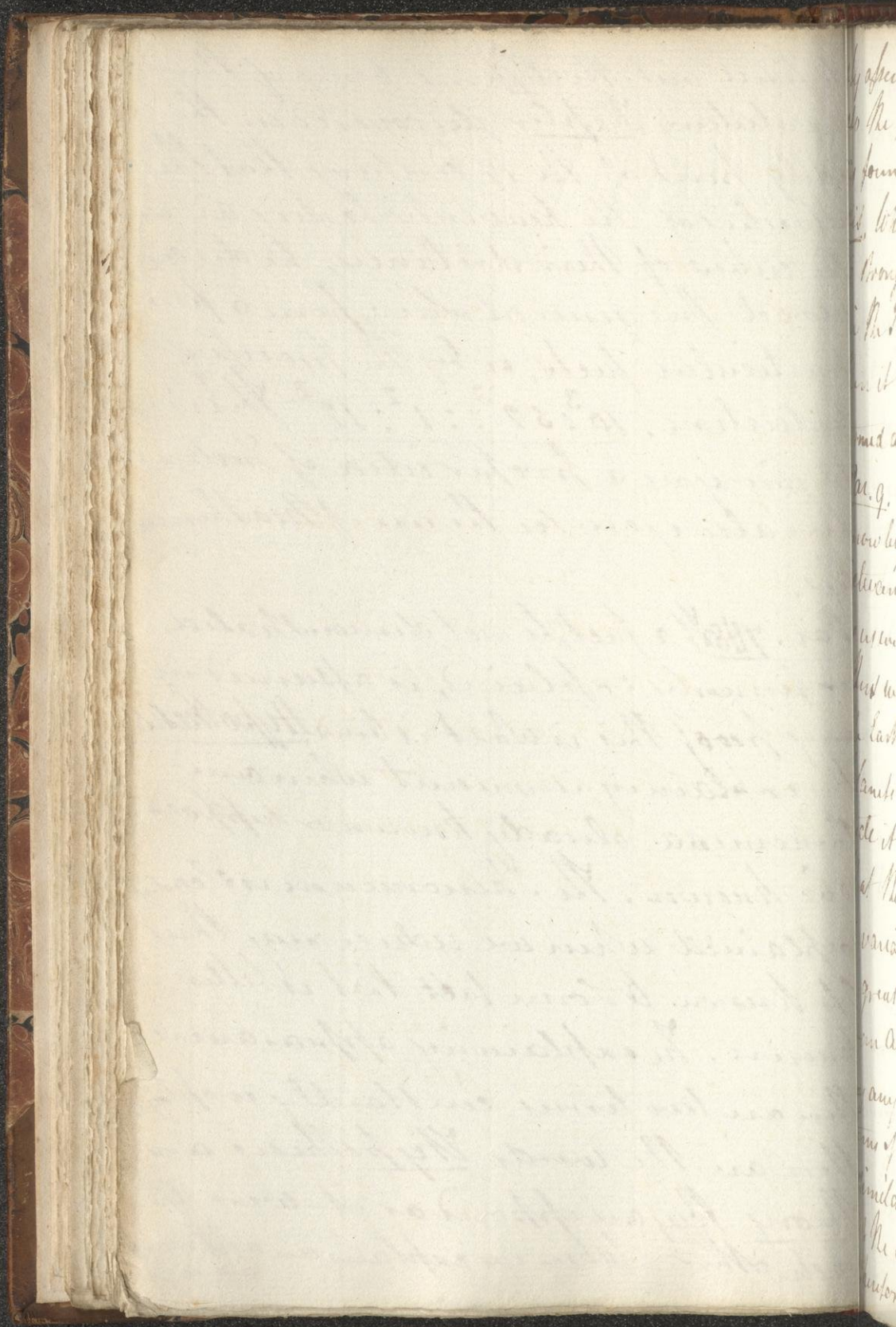
Nature are either changed, by a process, in their constitution & property, or they are not, the former than as I said before is Chemical the latter Mechanical Philosophy.

Par. 3 When we deduce general conclusions from a few particulars facts (the method discovered by Bacon) this is what is termed Induction, & it is from it all certain & accurate knowledge of Nature is derived. An example of Induction Suppose we were to enquire into the time of the revolutions of the Planets & the difference of their distance from the Sun; take the distance of the Earth call it 10 we know it revolves in a little more than 365 days. When we go to Mars we find it in the proportion of 15:10 there are simple facts, now Jupiter is much greater and using the same scale Jupiter is 52 the distance of Saturn 90 & its revolution 30 years; now here are nothing but insulated facts - but from a careful examination of these & trying



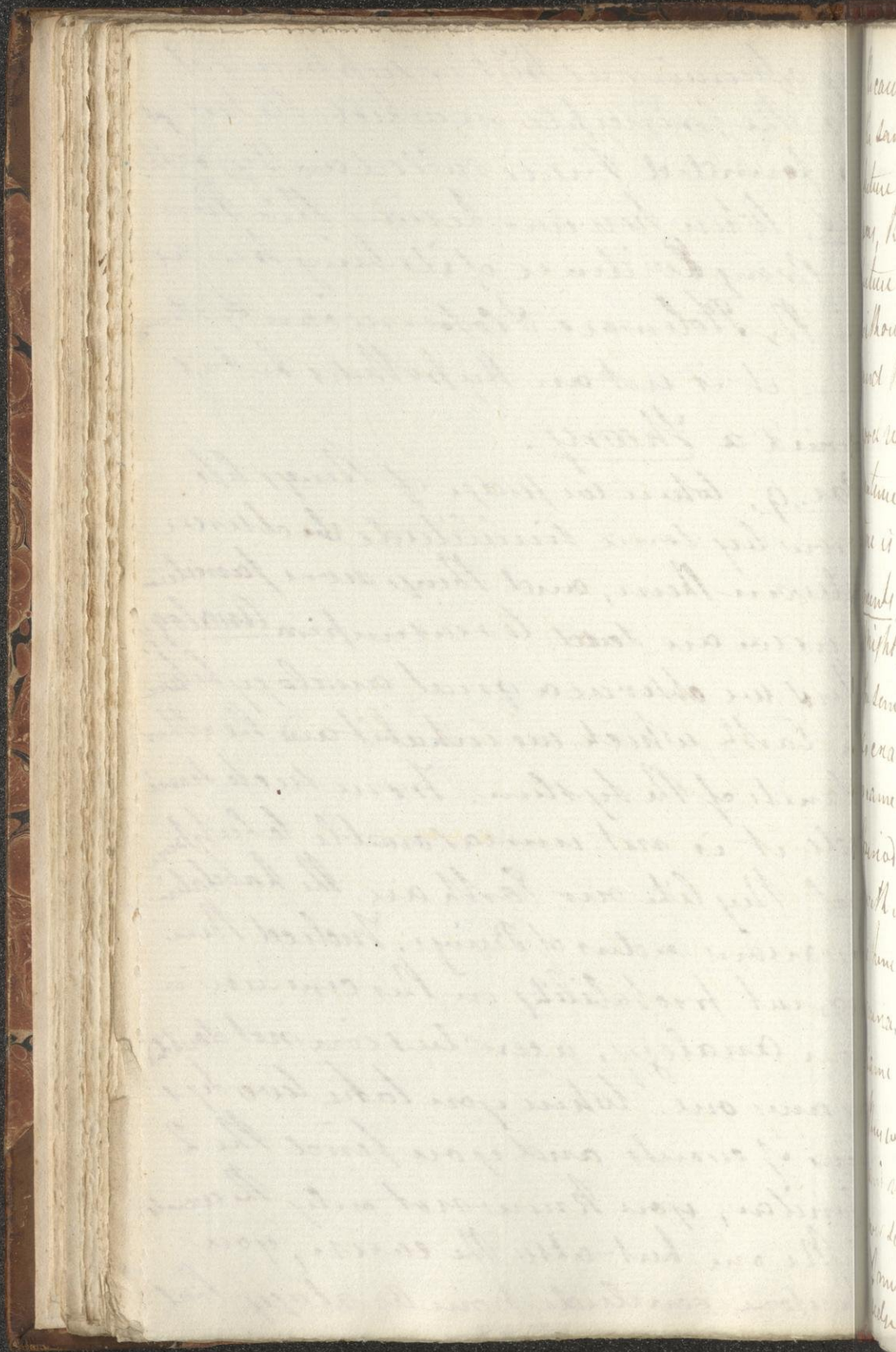
to find out the different times of their
revolution Kepler discovered in the
early part of the 17 century that the
velocities of the heavenly bodies are as
the cubes of their distances, he discov-
ered this general Law from a few
particular facts, or by the process of
induction. $10^3 : 52^3 :: 1^2 : 12^2$ This is
to give you a proper idea of Induc-
tion also you see the use of Mathema-
tics.

Par. 788 a fact, not demonstrated,
or properly explained, is assumed in
any proof this is what is termed Hypothesis
By explaining is meant when any
phenomenon already known or supposed
to be known. The Phenomenon is already
explained when we reduce any thing
less known to some fact that is better
known. The explaining appearances
then are two terms constantly employed
then are the words Hypothesis and
Theory they are opposed as it were to
each other. When we explain an appearance



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by affirming as true or supposing it
to be the principle on which the proofs
is founded this is called an Hypothesis,
when however besides this there
is strong Evidence of its being true as
in the Ptolemaic & Copernican Systems
then it is not an Hypothesis but is
termed a Theory.

Par. 9. When we judge of things, left
known by some similitude we observe
between them, and things more familiar
to us we are said to reason from Analogy.
Thus we observe a great analogy between
the Earth which we inhabit and the other
planets of the system. From such simi-
litude it is not unreasonable to suppose
that they like our Earth are the habitation
of various orders of Beings. Indeed there
is great probability in this conclusion
from Analogy, a conclusion not doubted
by any one. When you take two sys-
tems of events and you find the 2
similar, you know not only the events
of the one but also the cause, you
therefore conclude from Analogy that



The cause and events of the other were
 the same. Thus we consider that the
 future will be the same as time past
 was, the present moment was once
 future and the space was passed over
 without the Laws of Nature changing
 and thus from analogy we have very
 good reason for supposing it will
 continue unchanged. The course of Na-
 ture is a system of periodical move-
ments, thus the regular return of Day
 & Night, the revolution of the Seasons &c.
 In some countries the weather can be
 so exactly calculated, that one can
 name to a very great nicety the very
 period particular ~~Winds~~ will set in
 with us however this is not the case, there
 is here a greater variety in these pheno-
 mena, but still we are subject to the
 same regular periodical movements.
 Thus we have a regular Summer & Winter
 and no such thing as Snow was
 ever seen in the month of July. See
 I must mention a sort of Snow
 which is not easily reduced to prin-
 ciples

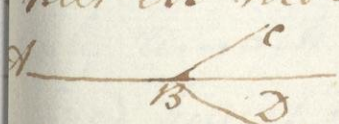
X Lx Hutton Mat. Rerations

That is the doctrine of chances it
 seems to be an imaginary analogy
 suppose there is an Urn containing
 12 counters 5 red & 7 white; suppose a
 person was to put his hand in & to take
 one, what chance is there of its being a
 red or a white, there are 12 counters
 & as there is 1 to be taken out of it, it
 may be done in 12 different ways, now
 there is 5 favorable to the taking out the
 white counter & 7 the white, the likely-
 hood therefore of drawing a white will
 be as $\frac{5}{12}$ & $\frac{7}{12}$ the drawing of a white. It
 is just so in throwing a die, if you
 throw but one and wish to know what
 chance you have of turning up the
 ace you will find it to be as $\frac{1}{6}$ the
 die being a cube, if you have 2 dice
 it will be $\frac{1}{36}$. This doctrine becomes
 useful in "Political Arithmetic" as it
 is termed, the pro: of the males to the females,
 of births to deaths &c.
 par 12 In tracing the ^{necessary} ~~natural~~ con-
 nection of natural phenomena, this
 doctrine is often of use: nothing exists

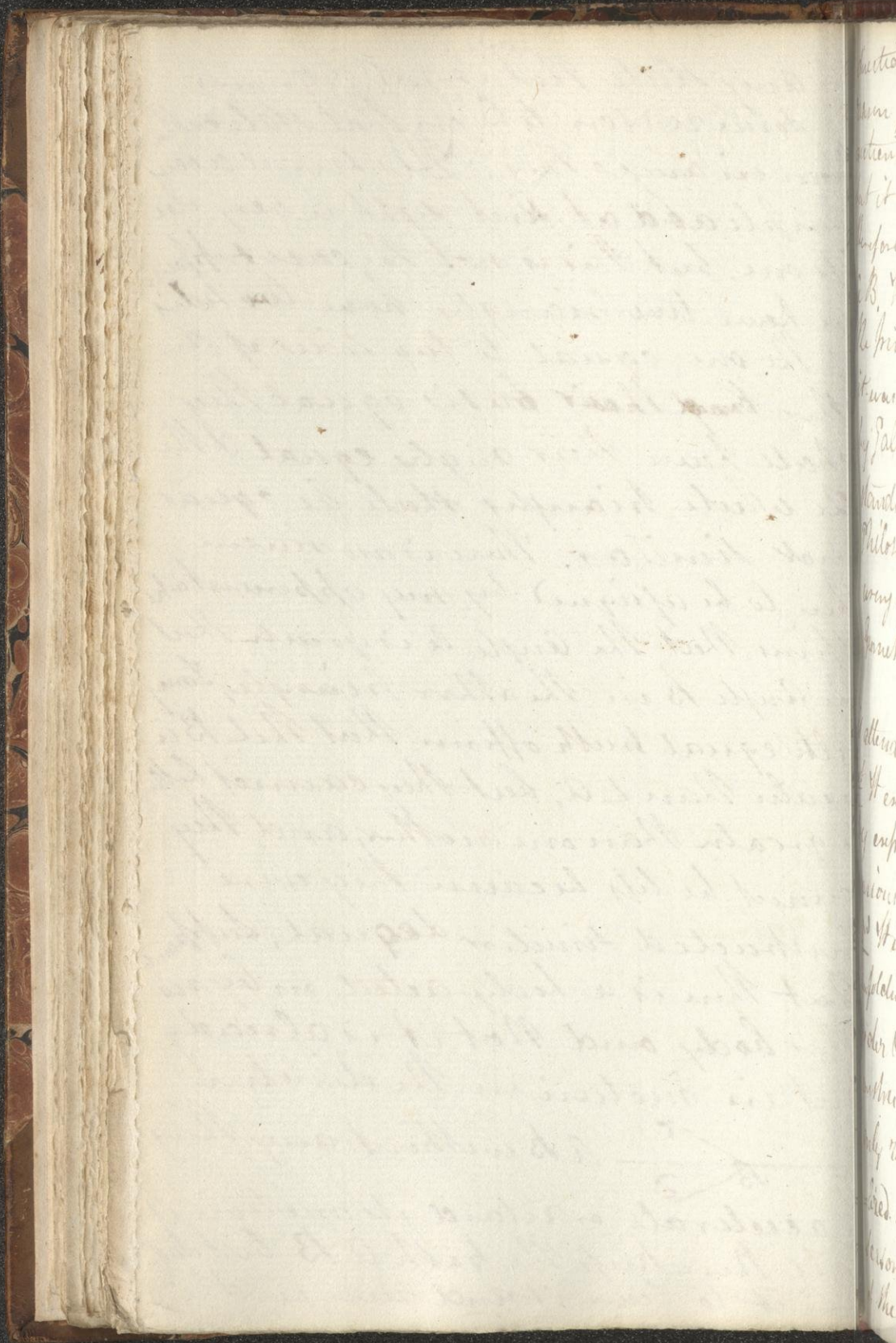
to accept
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in any state that is not determined
by some reason to be in that state rather
than in any other. This seems a very
simple and at first sight a very use-
less one, but this is not the case suppose
we have two triangles have two sides
of the one equal to two sides of the
other ~~triangle~~ ^{and} their bases equal they
shall have their angles equal & the
the whole triangles shall be equal
and similar. There is no reason
then to be assigned by my opponent who
affirms that the angle A is greater than
the angle B in the other triangle, I may
with equal truth affirm that the $\angle B$ is
greater than $\angle A$, but they cannot both
be greater than one another, and they
cannot be less because they were
constructed similar & equal. Suppose
that there is a body acted on by no
other body and that it is already
but in motion in the direction

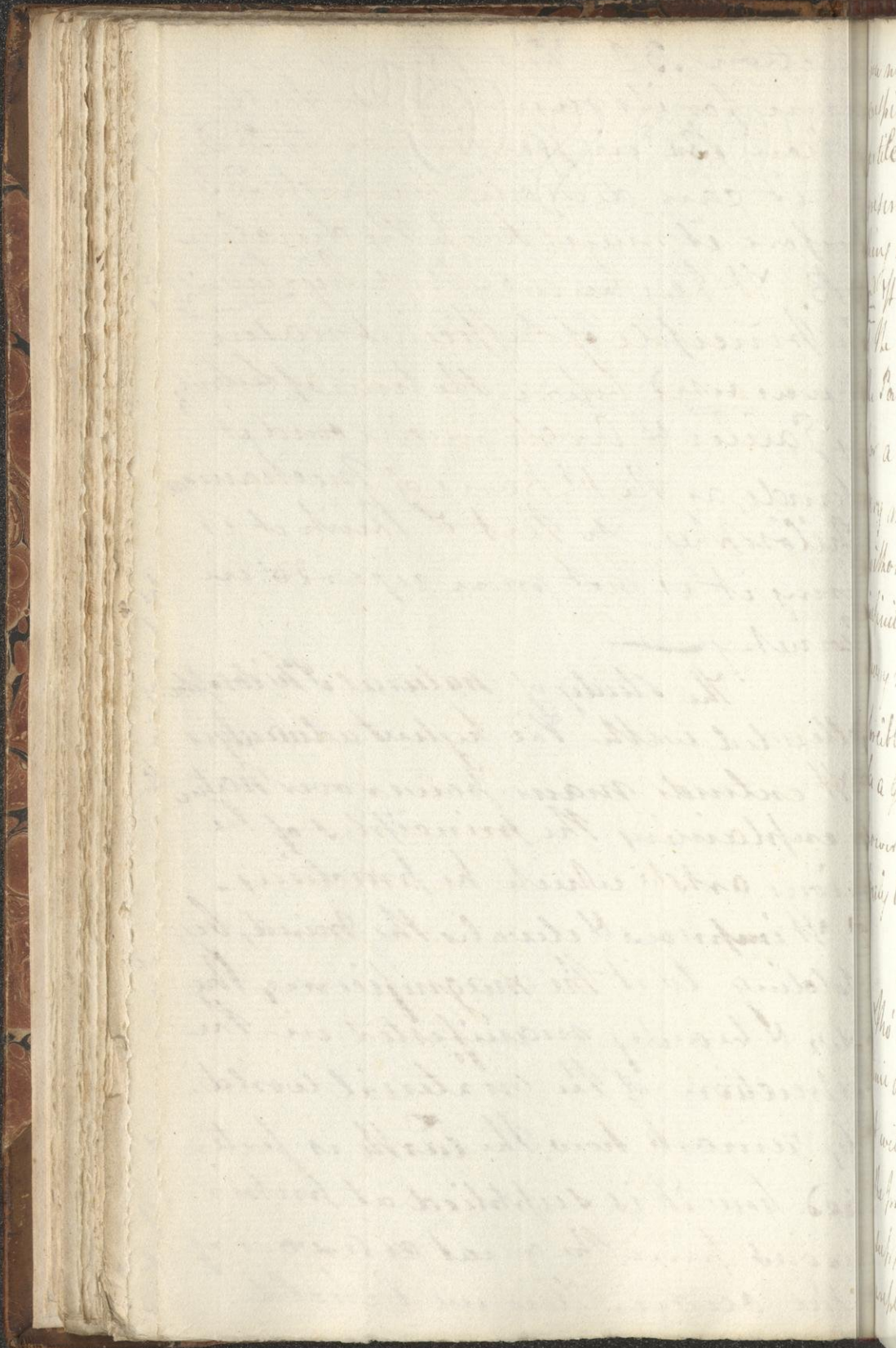
 AB without any thing

to accelerate or retard its motion it
will then keep the path AB but sup-
pose it to leave it and run in the



direction BC ⁽⁶¹⁾ but there is no
reason for its running in the di-
rection BC in preference to BD,
but it can deviate towards BD
Therefore it must keep the direction
a B. It has been called by Librius
the principle of sufficient reason
it was used before the time of Librius
by Galileo & Archimedes and it
stands as the 1st basis of Mechanical
Philosophy, so that I think it is
wrong it is not more regarded in
Germany —

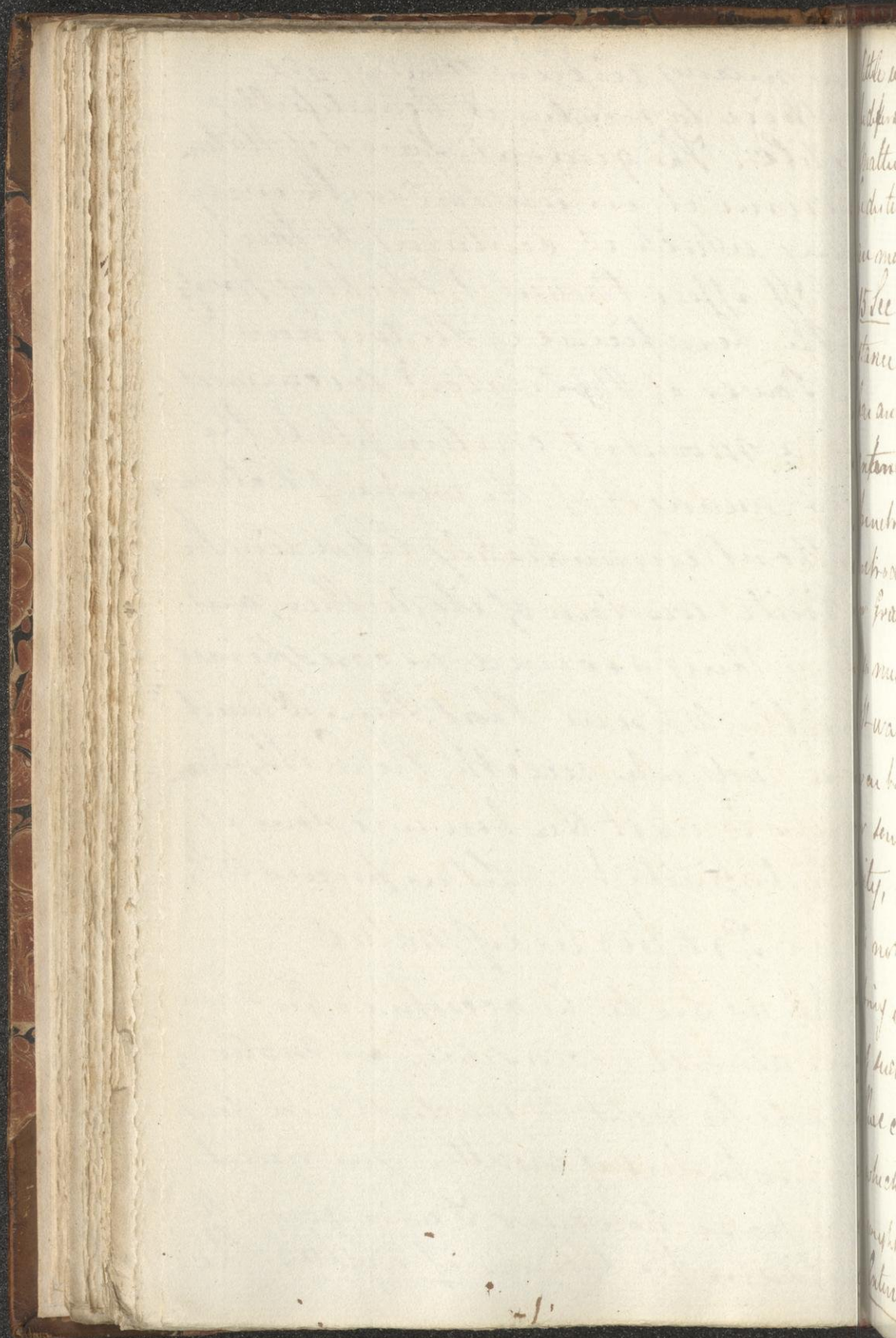
The study of Natural Philosophy
is attended with the highest advantages
1st It extends mans power over Nature
by explaining the principles of the
various arts which he practises.
2nd It improves & elevates the mind, by
unfolding to it the magnificence, the
order & beauty manifested in the
construction of the material world.
only remark how the earth is ferti-
lized. how it is supplied at proper
seasons from the great reservoir of
the ocean. Then we behold



how many circumstances all
conspire to render it beautifully
fertile. The general Laws of Nature
preserve it in unison with every
thing which it contains & thus
3rd It offers the most striking proofs
of the beneficence the wisdom &
the Power of the Creator! We cannot
for a moment contemplate the
very meanest of the works of Nature
without immediately beholding the
infinite wisdom of its Author, and
every thing around us conspires
forcibly to prove that there must
be a God who ruleth the Earth, whose
power is vast & whose wisdom is
truly infinite! Let us proceed to the

Properties of Matter

Tho' we are to be occupied for some
time almost exclusively on Motion,
it will be right to understand first
the properties of matter you must
suppose however I am going to
explain the Essence of Matter the

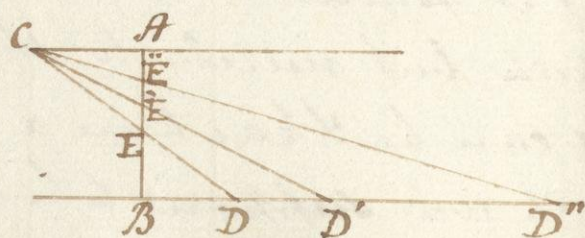


little we can say about it must
be deferred till the end of the course.
Matter and Body properly should
be distinguished, it is with Body we
are more immediately concerned.

15th Lec. Body is a substance (by sub-
stance we mean something that
has an independent existence)
extended in the 3 dimensions, im-
penetrable & moveable. I have not
introduced into this division weight
or gravity, it does not impress itself
so much on our senses as the other.
It was not long ago that a substance
was brought forward, the Philosophers
or sources of heat, which had no pre-
vity, this however on a little reflection
is not the case, I do not mean to
bring it forward as an example
of such, but merely to show that
there can be & has been a substance
which was supposed to be without
weight or gravity.

By

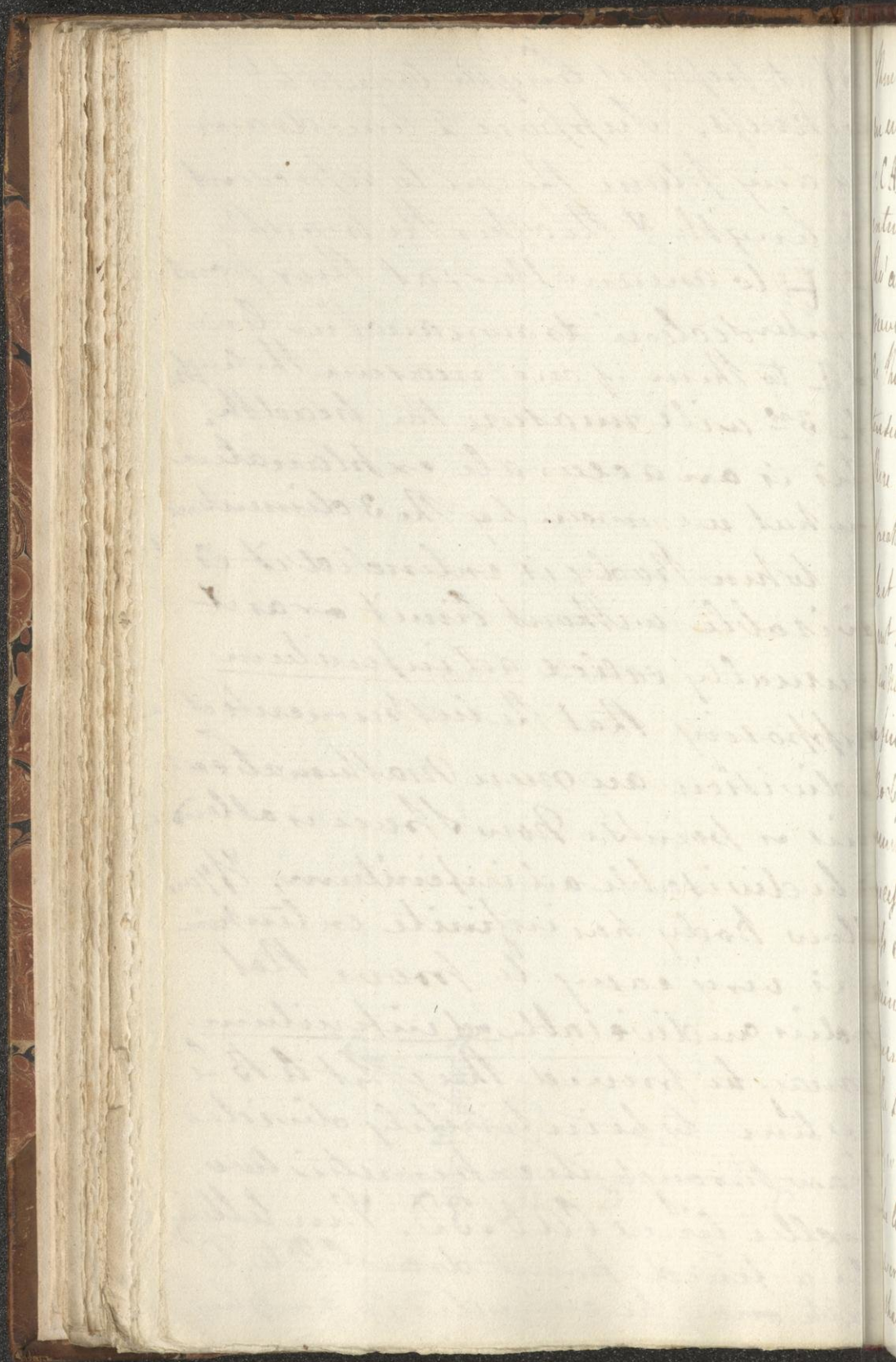
Extension in 3 dimensions is
meant.



D

that it possesses length breadth & thickness. Suppose 2 lines drawn in any plane the one to represent the length & the other the breadth at E to one another; at their point of intersection draw another line at L to them if one measure the length the 3^d will measure the breadth. This is an accurate explanation of what we mean by the 3 dimensions.

When body is extended it is divisible without limit or as it is usually called ad infinitum supposing that the instruments of division are mere mathematical lines or points. Now space is allowed to be divisible ad infinitum, if you allow body has infinite extension it is very easy to prove that body is also divisible ad infinitum. It may be proved thus Let AB be any line to be infinitely divided Draw through its extremities two parallel lines CA & BD . Then letting C be a fixed point draw CD to D which may be extended to any length



Thus the two triangles CAE & EBD
are evidently similar & $DB:BE$
:: $CA:AE$. Thus the farther D is
extended AE becomes the less but
tho' always approaching it will
never actually arrive at AE .
Therefore there is no limit to con-
tinuation we may here conclude that
there is none of divisibility. Whether
speaking regarding Mathematics, the
fact there is no matter which has
not the 3^d demonstrations there is no edge
in Nature which we may not suppose
a finis. The actual divisibility of
Body into parts, as the the parts
must be of finite magnitude must
necessarily be limited, it is neverthe-
less so facile of being carried to such
minuteness that the parts shall be
incredibly small. Without mentioning
the subtilty of odours or of light both
of which when told are hardly to
be believed, let us consider the
works of Nature among which we
shall find examples wonderfully minute.

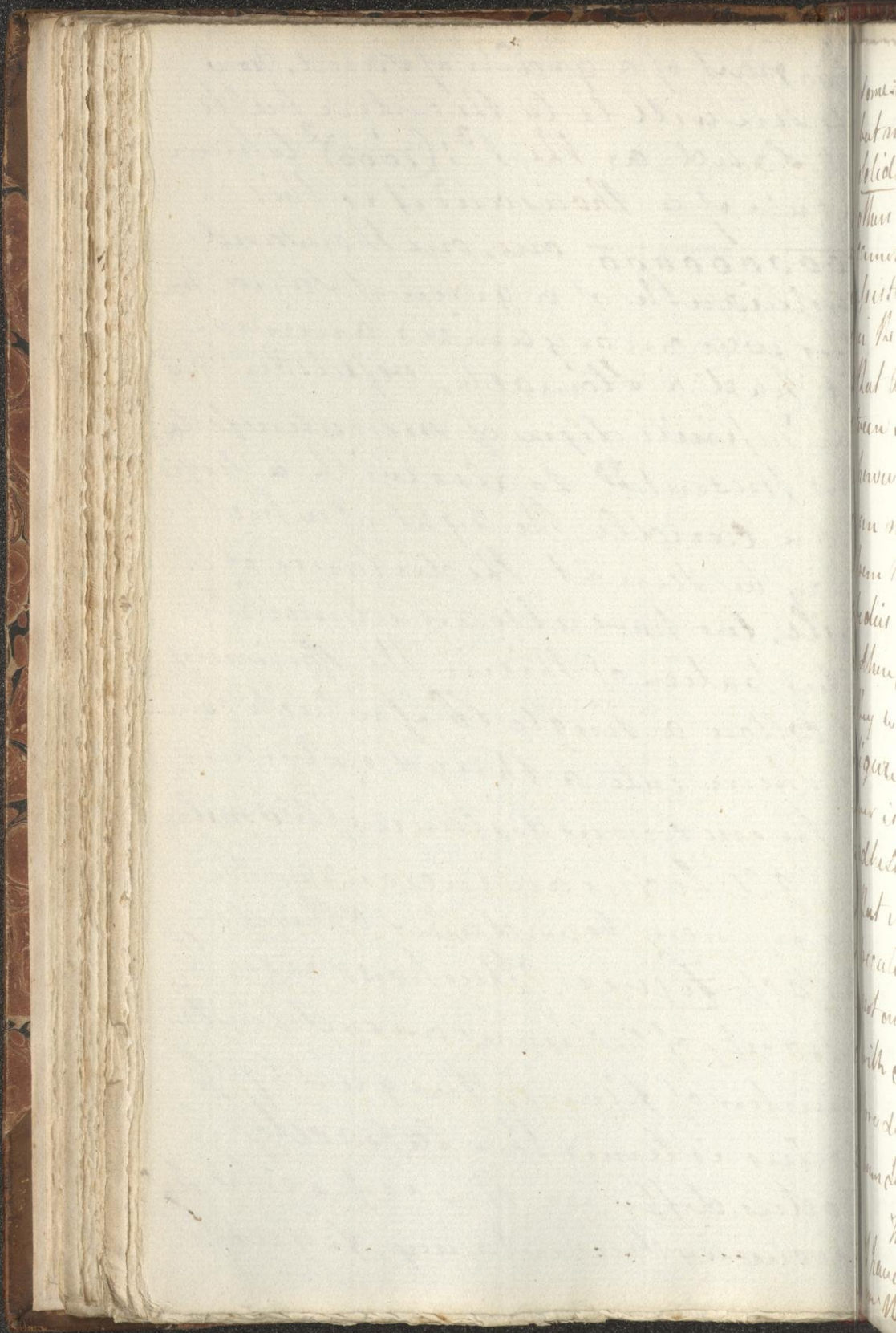
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we cannot expect that we shall
 in art be able to procure any thing
 so minute as we find in Nature
 Gold may be reduced so much
 that 30,000 leaves of it may now
 occupy the $\frac{1}{10}$ of an inch in thickness
 Now to see this more clearly, if you
 take 30000 leaves of paper which
 you know is by no means a thick
 substance, it would occupy 30 large
 folio volumes each volume from 4
 to 5 inches in thickness. The gold
 ing of Silver wire also. When an ordi-
 nary thick wire which at first was
 but 20 feet long is made by successively
 passing through the wires to extend to
 the enormous distance of 245 miles
 and the whole (which is the most in-
 credible part) to be gilded with
 2 or 3 ounces of Gold!! From Nature
 we know that Leonook observed mi-
 croscopick animals in a bytable
 water that had been exposed to the
 rays of the Sun; he gives the differ-
 ent diameters, he found that the
 smallest (calling it 1 in diameter)
 then, a 1000 of them would occupy

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$\frac{1}{1000}$ Part of a grain of Sand. Now
its size will be to the entire bulk
of Sand as the $1^3 : (1000)^3$ to have
a cube of a thousand it is this
 $\frac{1}{1000000000}$ one, one thousand
millionth of a grain of sand. Now
this was an organised animal
it had a Stomach, vessels &c. What
an infinite degree of minuteness does
this present? So also with a single
wax candle the light of which
may be seen at the distance of a
mile, we have also an admirable
illustration of this in the spinning
of cotton a single lb of which can
be spun into a thread extending
to the enormous distance of 50 miles.

All bodies are enclosed with
one or more boundaries & therefore
possess Figure. They have also the
capacity of receiving an indefinite
number of figures. This quality of
Bodies is termed their Capacity.
Bodies differ in their capacity for
receiving & maintaining figures.



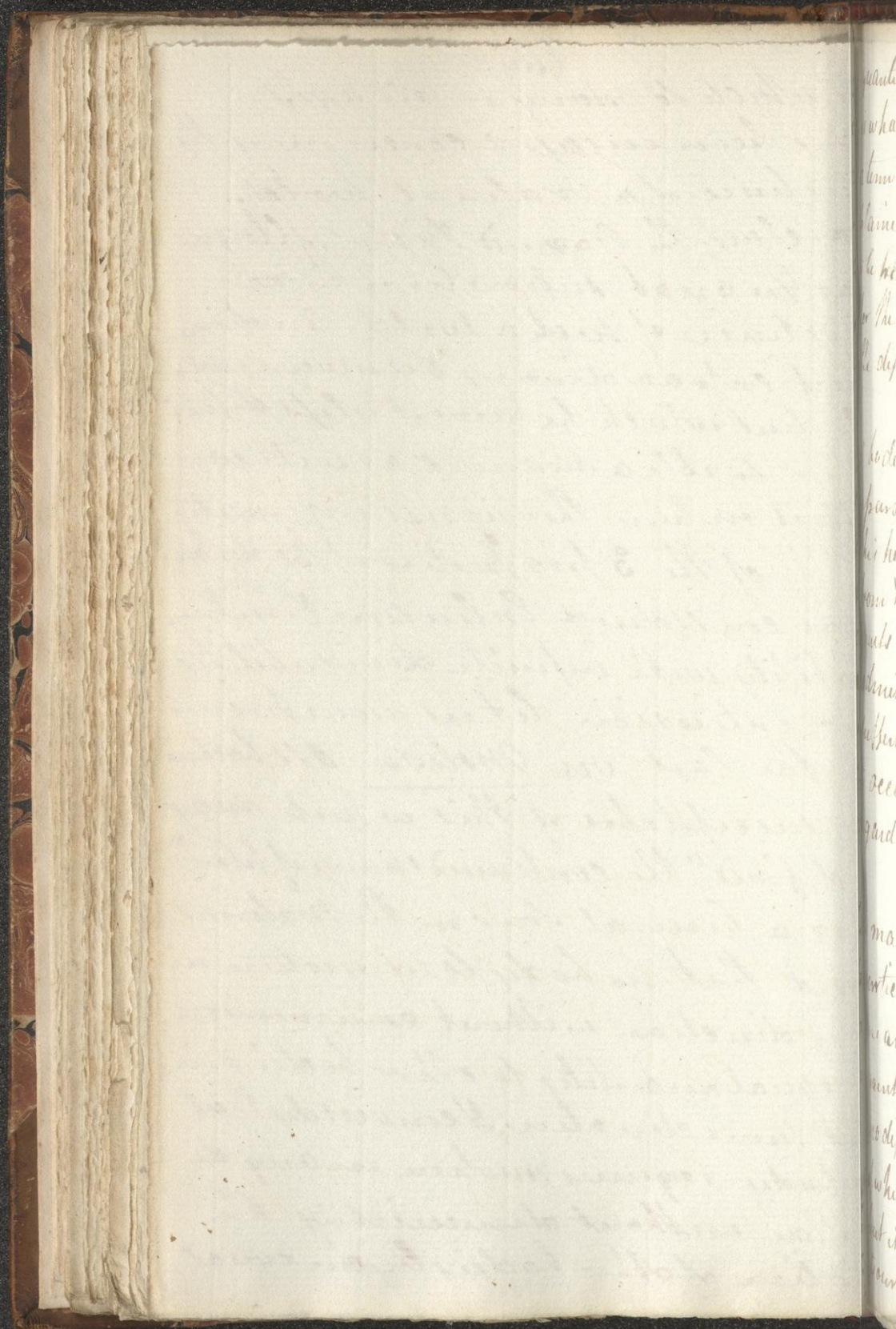
Some receive it with difficulty
 but maintain it easily as in
Solids which are called hard.
 Others receive figures easily but
 cannot maintain it without the
 assistance of some other body as
 in the case of Water. It was thus
 that Aristotle distinguished be-
 tween Solids & Fluids. It is not
 however strictly true that Fluids
 can maintain no figure for
 from the power of cohesion in ale
 bodies as well as in Fluids they often
 adhere, as in the drop of water. When
 they will be found of a spherical
 figure. This kind of cohesion how-
 ever is more properly termed merely
 adhesion. Many bodies have figures
 but in their natural state are
 peculiar to them. This is the case
 not only with Plants & Animals but
 with certain mineral & chemical
 productions called crystals usually
 bounded by plane surfaces.

In none of my preceding lectures
 I have not thought it necessary to go
 over the Metaphysical or empirical

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in which so many in all ages
have been engaged concerning the
existence of a material world.
Barclay the learned Bishop of Cloyne
was the great supporter of the non
existence of such a world. An opinion
most extraordinary & unaccountable
but which he nevertheless defend
ed in so able a manner as will con
flect on him the highest integrity.

Of the 3 properties of Body we
have considered Extension & Impen
etrability with infinite divisibility
and extension let us now proceed
to the last viz Motion All bodies
are susceptible of this which may
be defined "the continued change of place"
It is a General Law in the Material
World that no body loses motion in
any direction without communicating
an equal quantity to other bodies in
that same direction, & conversely that
no body acquires motion in any di
rection without diminishing the
motion of other bodies by an equal



quantity in that same direction. This is what is termed the "Inertia" of Matter a term which will be afterwards explained when Motion comes properly to be treated, being mentioned here only for the sake of order & being part of the definition of Body.

The force with which the parts of bodies resist any endeavour to separate them is termed Cohesion. This however must be distinguished from Impenetrability. Cohesion prevents its parts being separated to admit another. Impenetrability suffers not another at the same time to occupy the same place without regard to its particles.

We may conceive a Body to be made up of small assem. blages of particles or corpuscles adhering to one another. These are called the Elements of Body. Cohesion is variously modified in term it causes Hardness of which there is no precise standard but is generally reckoned in relation to our own force. When a Body

x By Ductility is meant the extension
of Metals when cold by the force of rollers
malleability is when that extension is
caused by percussion or strokes of a hammer.
The arrangement of the Metals ac-
cording to this power is the following
Gold, Platinum, Silver, Mercury when it
is poured, Tin, Copper, Lead, Iron, Nickel,
Zinc &c.

scratches Glass we generally call
it hard, such is the case with the
precious stones. When a Flint is
struck by a piece of Steel does not suf-
fer the sparks to come from the steel
it is from the flint, the steel overcoming
its Tenacity. These sparks are round
when collected and remained to cool
they can evidently be seen to be pieces
of Flint that have been struck off in
a state of ignition. The converse to this
is softness which I need not describe
In stone it causes Tenacity or toughness
Thus in some rocks the fragments
are small & very brittle, but in Tenacity
they are large and without many cracks
and when broken break not into splin-
ters but into large & solid pieces. The
next modification is Ductility
as in gold. Thus if you strike with
a hammer or other instrument a
piece of Glass it is immediately lost
into a 1000 pieces. If however a piece
of Iron or chiefly Gold were thus struck
it would not break into pieces but
would only then increase its cohesion

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the more the Hammers were applied
 when two pieces of Iron are heated
 red hot they may be welded almost
 into the same piece. The Silver wire
 already mentioned is a good exam-
 ple. This is what is termed Ductility.
 The next modification is Fluidity.
 The substance here yields to the least
 force. This is the essence of Thickity while
 the essence of Solidity consists in
 resistance to a great force. Thickity
 does ~~not~~ as was mentioned already
 admit of the attraction of Cohesion as
 is evident from the Globular shape of
 opumes. In Mercury this Cohesion is
 still more evident Drops being always
 found of nearly the same magnitude
 are used as nice dis-criminations as
 measures of medicines. In other substances
 some fluids have no Cohesion what-
 such is the case with all Elastic
 fluids as Air & all gases have Air
 expands without any limit but
 it is its own weight not the force of
 Cohesion that keeps together its par-
 ticles —

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This is a page from a handwritten manuscript, likely a letter or a personal journal entry. The text is written in a cursive script, characteristic of the 18th or 19th century. The page is numbered "11" in the top left corner. The text is written in a dark ink on a light-colored, slightly aged paper. The handwriting is fluid and somewhat slanted. The text is arranged in several lines, with some lines being longer than others. The overall appearance is that of a well-preserved historical document. The text is as follows: "11
This is a page from a handwritten manuscript, likely a letter or a personal journal entry. The text is written in a cursive script, characteristic of the 18th or 19th century. The page is numbered '11' in the top left corner. The text is written in a dark ink on a light-colored, slightly aged paper. The handwriting is fluid and somewhat slanted. The text is arranged in several lines, with some lines being longer than others. The overall appearance is that of a well-preserved historical document."

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Art. 23. All Bodies at the Earths surface if left to themselves descend in straight lines towards that surface. This tendency or disposition to fallen weight. By the word Tendency we are generalizing the facts. The weight of a given body may be employed to measure the weights of all other bodies. This as you shall see by Why is done by the Balance. The directions in which Bodies fall in different places of the Earth tend nearly to the centre of it.

If I was to suspend to plummet lines from each end of the table, altho' there certainly is a difference in their direction yet it is so slight we should not perceive it; but if we suppose this circle to represent the Globe & A & B two different Observers the plummet line will be seen evidently to differ very much in direction, and of course the nearer A & B are to each other the smaller will be the L. All points there are not very far distant from each other on the surface, the directions are nearly parallel, the centre being in

[Faint, illegible handwriting across the page, likely bleed-through from the reverse side.]

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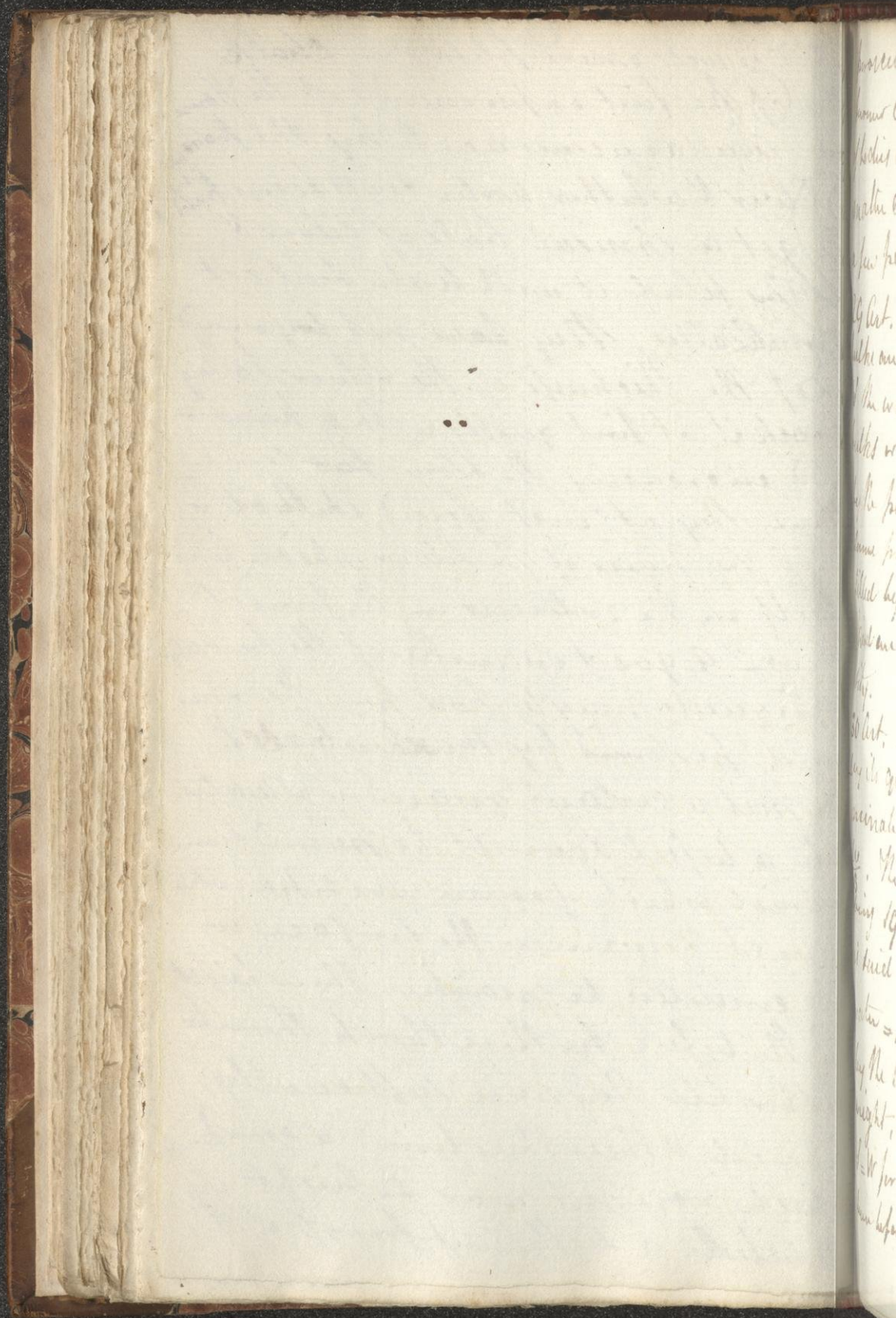
comparison so far removed. If the distance be 60 nautical miles this is a degree, if a Mile then a minute.

25 Art. If we conceive the weight of bodies produced by a force applied to each of their elementary particles urging it downwards this force is called Gravity. The weight of a Body is the product of the gravity of a single particle by the number of particles. Thus if W be weight g gravity of each particle n number of particles $W = ng$. In all bodies the force of gravity is the same. And if therefore the air were extracted all bodies in such a medium fall to the ground in the same instant of time. On this principle a Guinea & a feather (as shall be shown in a few days) in the exhausted receivers of our Air pumps fall at the same time to the bottom. All bodies have empty spaces disseminated through them in the form of pores more or less minute. This property is called their Porosity. In Solids they can be seen generally by the naked eye & always by the microscope

[Faint, illegible handwriting, likely bleed-through from the reverse side of the page.]

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(75)
This is well exemplified in Chalk
One of the first experiments of the Roman
Academics was to try the power
of Silver & whether water could be condensed
He got a spherical ball of silver &
having filled it with water sealed it
hermetically. They have not informed
us of the thickness of the silver, having
struck it at first gently with a hammer
and increasing the blows for some
time they at last forced the water
thru the pores of the silver which found
itself on the exterior in the form of
Dew - A good example of the force
of Liquids may be had from the experi-
ment performed by Muschenbroek
He put a certain quantity of water
into a vessel & over it he poured some
nitric which of course was separated
from it & swam on the surface in
this condition he marked their height
in the vessel he then shook them to-
gether till they were sufficiently
mixed & they thus formed a compound
which rose not near so high in
the vessel a sufficient proof of the



76
porosity of the liquids in their
former condition. From this property
of bodies it follows that the particles of
matter can only touch one another in
a few points.

29 Art. If in two Bodies, of which the
bulks are B and B' , & the weights W &
 W' the weights are proportional to the
bulks or $\frac{W'}{W} = \frac{B'}{B}$. The space occupied
by the pores of these bodies bears the
same proportion to that which is
filled by solid matter. Bodies of this
kind are said to have the same den-
sity.

30 Art. The weight of a body divided
by its quantity of matter is deno-
minated its Specific Gravity or
 $\frac{W}{B}$. The specific gravity of gold
being 19 times & $\frac{1}{2}$ that of water it
is said to be $\frac{W}{B} = 19.5$ while $\frac{W}{B}$ of
water = 1. The spec. Gra. multiplied
by the bulk is then equal to the
weight, or if be the spec. gravity $B \times$
 $S = W$ for it follows from what has
been before shown viz $\frac{W}{B} = S$.

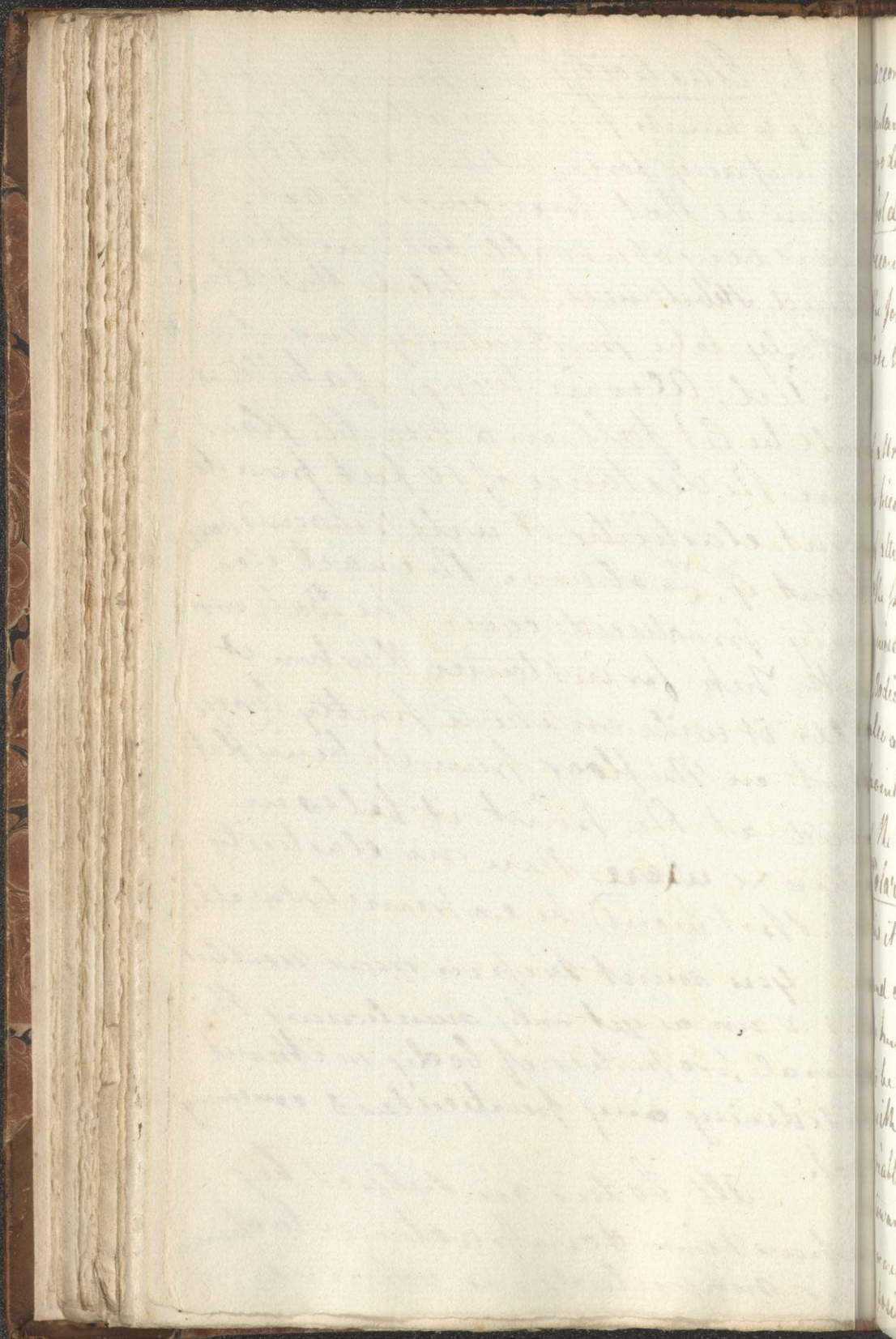
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32 Art. Elasticity is a power by which a body when its figure is altered by the action of any force, returns that figure as soon as that force ceases to act.

This is very observable both in Solids & fluid Substances. The Solids this it particularly to be particularly remarked in Steel. Also in Ivory, if a billiard Ball be let fall on a Marble floor from the distance of 10 feet from its great elasticity it will rebound ^{back} about 9. To observe the exact elasticity produced cover the Ball over with Tuck for instance when it falls it will make a pretty large spot on the floor from its being flattened at the point it falls on whereas where there no elasticity the spot would be extremely small.

You must keep in your recollection that I am as yet only mentioning the general properties of body without considering any particulars concerning each

All bodies are subject by expansion & contraction to change their magnitude or volume



(78)
according to certain Laws within
certain Limits. In expanding they
produce Heat, & in contracting
Cold. They are therefore said to
become hot & to enquire heat in
the former case & to become cold or
lose heat in the latter case.

Certain Minerals have a power
of attracting Iron & of communicating
to pieces of that Metal, the power
of attracting & repelling one another.
The power which is thus commu-
nicated is termed Magnetism.
Bodies possessing magnetism have
also a tendency when left free to
point towards a certain quarter
of the heavens. This is called their
Polarity. Among its many prop-
ties it in the 1st place attracts Iron
and other ferruginous matter. 2^d
to have a Magnet is placed does
to be at liberty to move itself
with freedom it turns one & the same
nearly the same part of the surface
towards the North pole of the Earth
or nearly to it, & of course the op-
posite part to the South pole

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These points are called the poles of the
 Magnet. 3rd When two Magnets are
 placed so that the North pole of 1
 of them is opposite the South pole of
 the other, then they attract each other,
 but if the South pole be placed oppo-
 site to the South or the North opposite
 to the North pole of the other then no
 attraction but repulsion takes place.
 The North magnetic poles of the same
 name repel each other, those of differ-
 ent names attract each other. This
 property of magnetic attraction is pos-
 sessed not only by Metals, but also
 by some Minerals as in which Stone
 which in some degree attracts Iron
 filings. Some bodies again by friction
 have the power of attracting & repelling
 other bodies. This is called Electricity
 as in the case of 2 pieces of wax & Glass,
 but particularly in two pieces of Amber
 from which latter, Electricity was first
 discovered. The friction must be
 between different bodies as a piece of
 wax & a piece of Glass, or a piece of
 amber & Resin &c. if however the

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friction is caused between two of the same kind it causes repulsion. On performing the experiment when the air is dry as in clear frosty weather we may distinctly perceive flames or rather sparks issuing from them.

The Chemical action of metallic substances on one another produces a like tendency in bodies communicating with these substances according to a certain rule. This power is termed Galvanism from the discoverer Galvani. It is a power of the most forcible nature overcoming the most powerful cohesion & resolving bodies of all kinds into their elementary & constituent parts. Tho' this discovery was made in Italy, Britain will ever have a considerable share in the merit of it. From the discoveries he has made the name of Davy will ever be remembered equally with that of Galvanism—

When bodies are free to obey the impulse communicated to them the science which treats of their motion is termed Dynamics. But when the bodies are not left at liberty to obey the influence the science which treats

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of this motion is termed Mechanics
when the Bodies which receive the
impulses be Fluids then there is a modification of the principles of Dynamics & the Science is termed Hydrodynamics.
In each of these three there are cases in which the forces conceived to act balance one another & produce not motion but rest, to this the name Statics has been applied. The case in Fluids forms the branch Hydrostatics. When in motion Hydraulics. The same terms are used with air & Gases or Aeronautics & Aerostatics.

It is now proposed to
the consideration of

See page 46, The Theory of
Motions —

See p. 85

Dynamics

43 Art. When a Body changes its place continually, it is said to move or be in motion.

44 Art. A moving Body cannot ~~pass~~ from one ~~space~~ to another without passing thro' every intermediate point.

That is, whatever be the ~~path~~ it describes, it must intersect all the places that can pass any how in the interval between two points. — Thus sup

A
 D

 C
 B

 Suppose there are two points
 as A & B. Between them a line
 CD. This line may be supposed
 to be produced to infinity both ways
 then A before it can reach B must
 evidently cut the indefinite line CD.
 This strictly speaking is an Axiom.

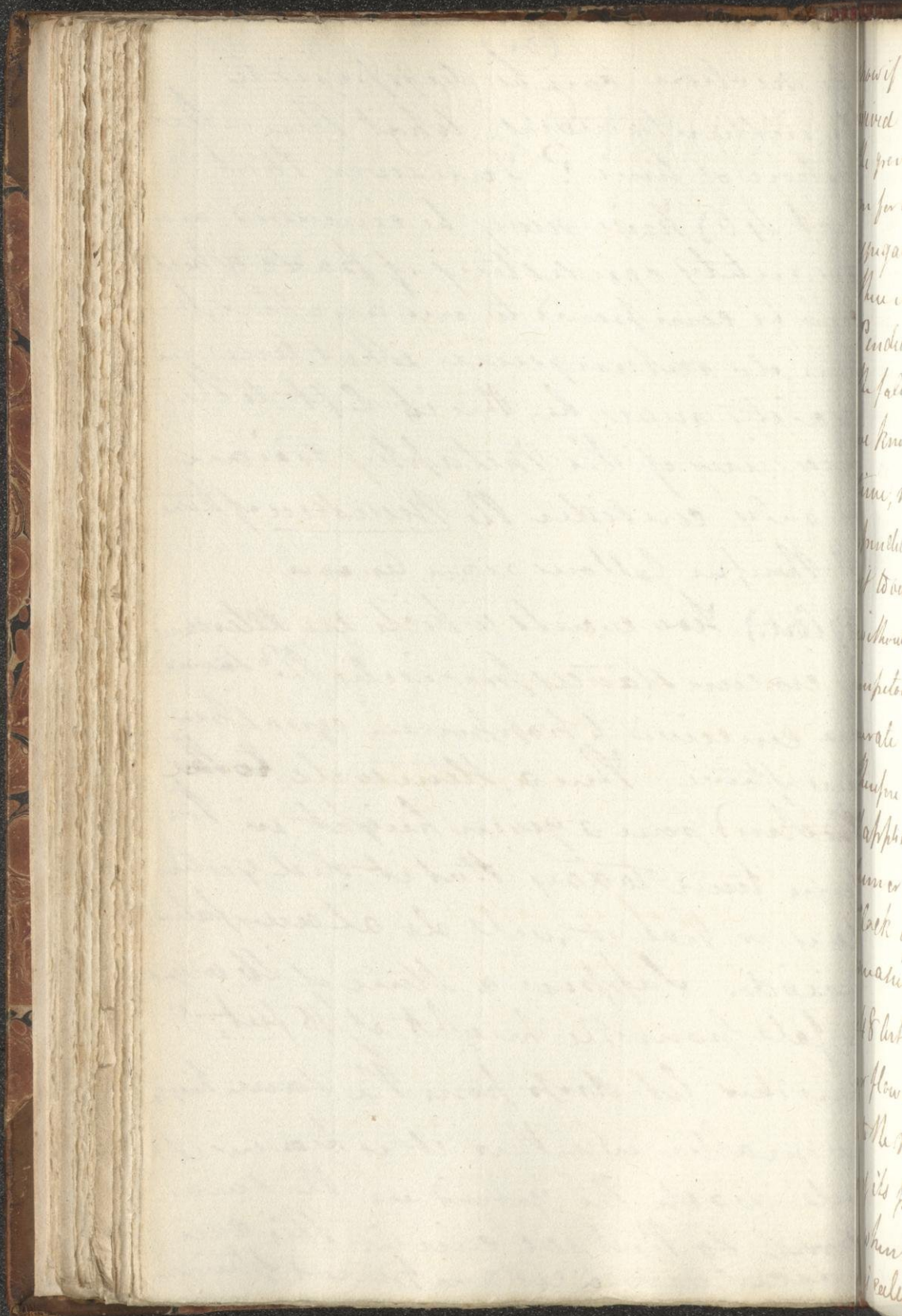
Art. 45. The ideas of space & time are both necessarily involved in the idea of motion. When we speak of motion from one point of space to another time is necessarily directed for there must be an interval of time during motion.

See p. 86

See p. 86

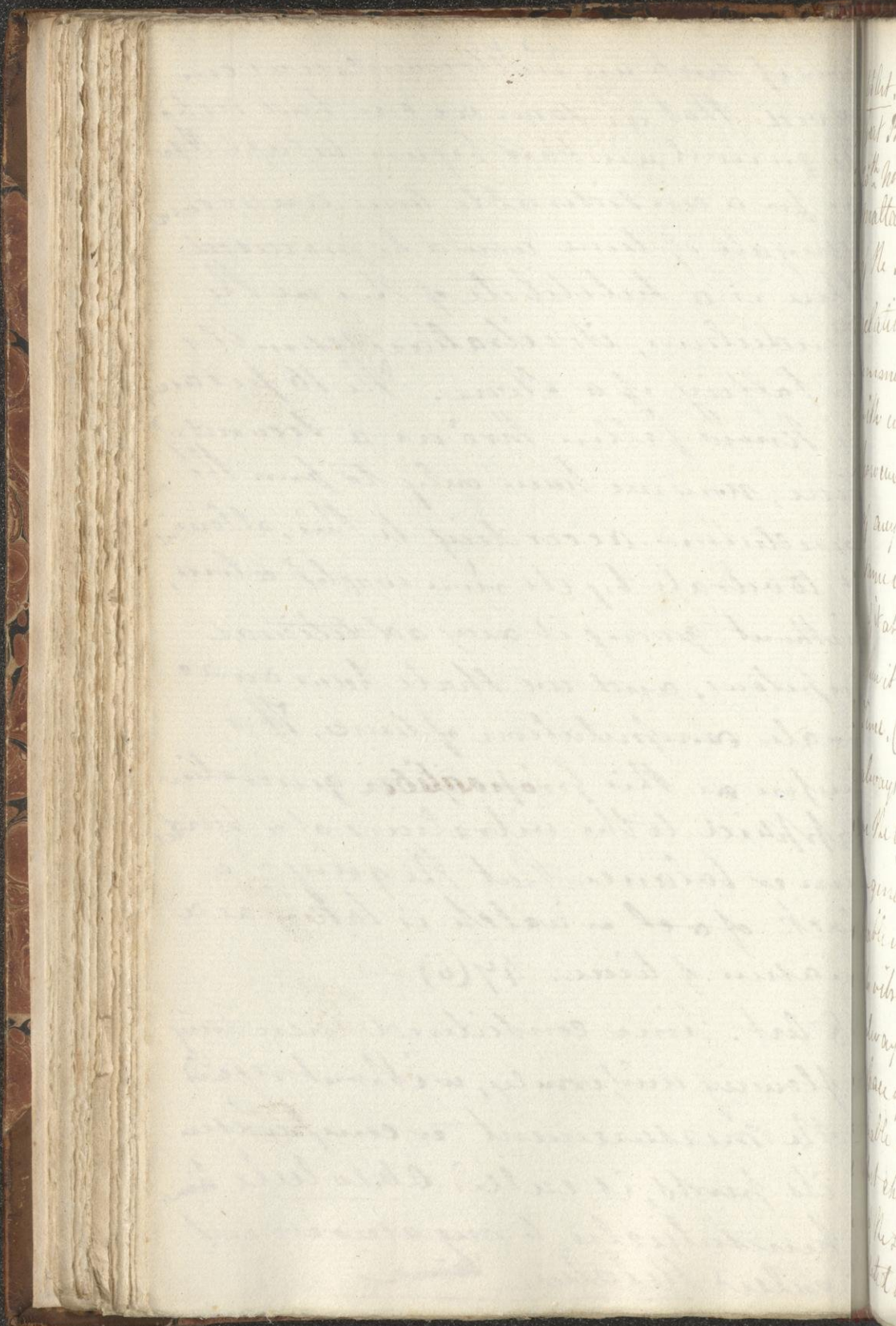
No motion can be supposed to be instantaneous. What then is this notion of time? I answer that (Art 46) Time may be conceived as a quantity consisting of parts which can be compared to one another, but here do not enquire what time in reality may be, this is left to the enquiry of the Metaphysicians we only consider the Measure of time. It therefore follows as an Ancon

(47 Cor.) Two events which are determined by circumstances precisely the same are conceived to happen in equal periods of time. Thus a stone will ~~fall~~ ^{be} thrown from a given height in the same time today that it did yesterday or that it will do at any future period. Suppose a stone of 16 weight to fall from the height of 16 feet, & another let drop from the same height no matter whether it is heavier it will reach the ground in the same time so that we can in this case ascertain a certain period of time

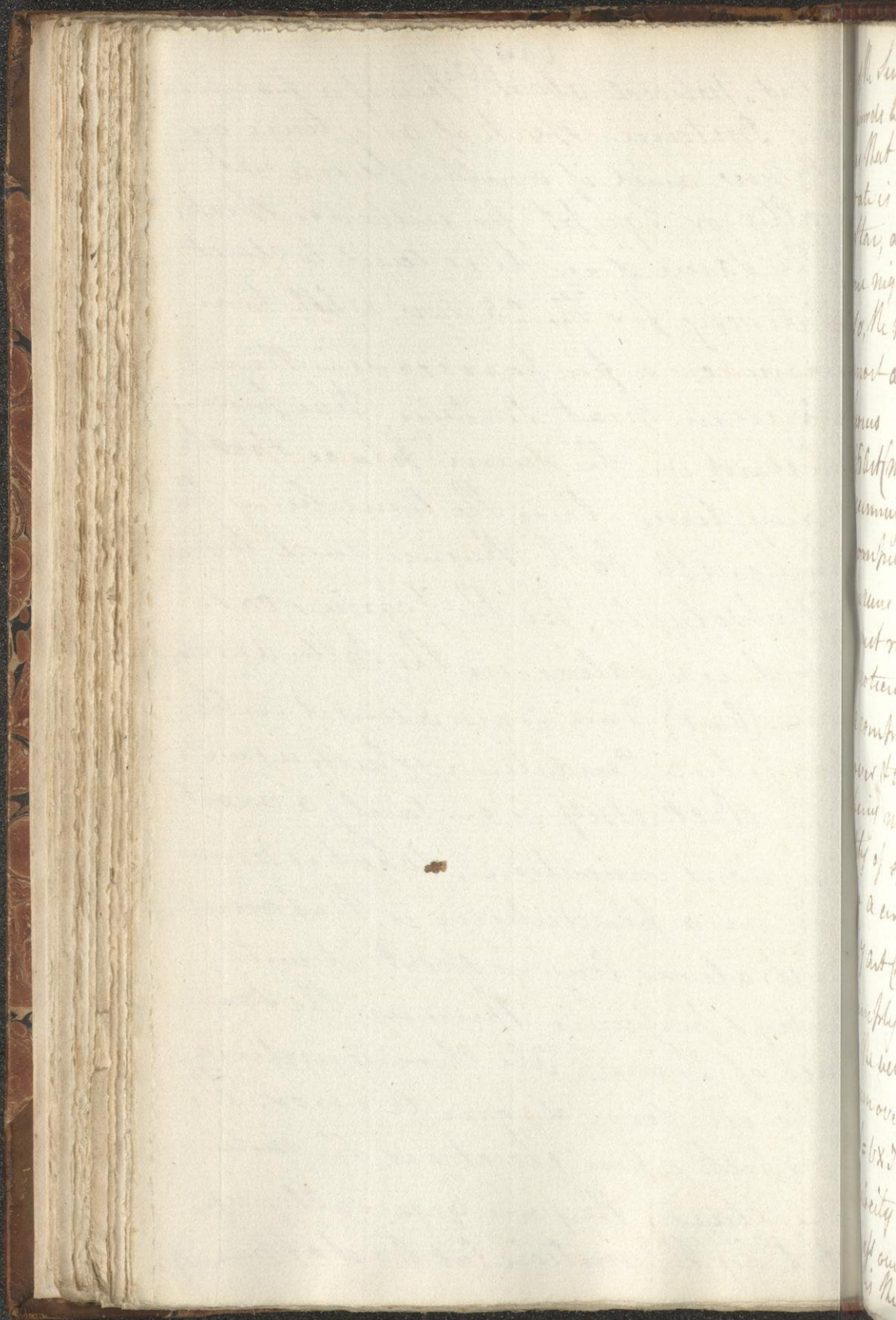


now if such an instrument was conceived that as soon as one had reached the ground, another began to fall & so on for a considerable time an accurate aggregate of time would be procured. There is a substitute of this in the Pendulum, its vibrations resemble the falling of a stone. The 16 feet we know fall in a second of time, now we have only to form the pendulum according to this, allowing it to vibrate by its own weight alone, without giving it any additional impetus, and we shall have an accurate computation of time. This therefore on this proposition generalized & applied to the vibrations of a pendulum or balance that the going of a clock or a watch is taken as a measure of time. 47(b) —

48 Art. Time considered increasing or flowing uniformly, without regard to the measurement or comparison of its parts, is called Absolute time when subjected to measurement is called Relative time.



4th Art. Noticed above. Thus if a person in Great Britain speak of any time as 25th Nov. and if another person at Malta or Egypt for instance speaks of the same day he is said to do it relatively for the 25 Nov. with him commences a few hours earlier than with us in Great Britain. Now persons however in the same place speak of any time then the time being the same with both they are said to speak of it absolutely. In the former case then it is relative in the latter absolute Time. (Cont) Time is measured in Clocks always by a Pendulum which as well as the Clock itself is certainly a most ingenious invention. What is remarkable in a pendulum is, that whether its vibrations long or short it will always perform them in the same space of Time. All Chronometers are liable in some degree to error. The best check upon clocks is the motion of the Stars, they are generally regulated by the motion (at least appeared)



of the Sun which however will after
wards be shown not to be so regular
as that of the Stars the most accu-
rate is the observance of a certain
Star, directly South for instance
one night, mark when she is exactly
so, the night after, this will be the
most accurate computation of 24
hours

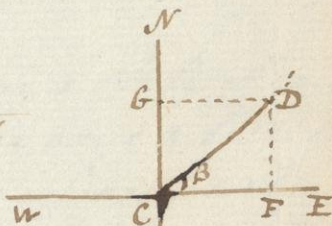
46 Art (mentioned above p 83) as in the
running of a Horse the velocity is
computed by the length of space
he runs over in a certain time. We
must remember not to confound
motion & velocity. The former being
a complete Idea of the space run
over & time employed & the latter
being merely the ratio of the quan-
tity of space which is run over
in a certain portion of time.

47 Art (mentioned above p 83) which is
simply demonstrated. Thus making
V the velocity per second. S the space
run over & T the time employed
 $S = V \times T$ for if a Body move with the
velocity of 3 feet per second it must
pass over ~~twice~~ 3 or 6 feet in 2 seconds,
this then is the first Law of motion

& In other words. Suppose a ship to
 sail N E now it comes to be a question
 how much has she gone to the N & E.
 Suppose N & E the meridian lines. The
 ship sails in the known line **AB** now
 in order to ascertain how far she has gone
 to the North & East let fall the perpendicular
 from **C** to **AB** this will give you her
 distance she has gone to the North &
 East. Suppose **AB** the
 distance is known & **AC** **AB** what
 is the length **CA**. Let **CEB** be denoted
 by β then **CB** **A** is its complement
 or what it wants of 90° , as Radius always
 supposed as 1) $\therefore \cos \beta :: AB :: AC$ then
AC will be known by multiplying
 it in $\cos \beta$, $ac = AB \times \cos. B$. Now

consider in the considerations
from which the others are easily deduced.
From this follow easily (48 & 49 Art) ~~or~~
from Algebra if $S = V \times T$ then $V = \frac{S}{T}$ as
also $T = \frac{S}{V}$. Thus then there are found
they may all be thrown into a Geo
metrical form thus from the ^{1st} Equation
 $S = V \times T$ comes $S \times 1 = V \times T$ For $S : V$
 $\therefore T : 1$.

50 Art. This figure is
to explain the velocity
of C in the direction of
 CN . The proof is however
better shown under Art 51 ~~Art 50~~



51 Art. Thus if the $\angle ECD = \beta$ is
and if CD and β be known, at D let
fall the perpendicular DF then we
say as $R : \cos. \beta :: CD : CF$ and $CF =$
 $CD \times \cos \beta$ This is the Easting, the
Northing is found supposing CD the
track of a ship by finding DF
in the triangle CDF as it is $= CG$
the Northing thus $R : S \beta :: CD : DF$
then $DF = CD \times S \beta$.

52 Art. The increments here are
not by $C \& T$ with points over them
not accents for then they would be

for the rate per hour $ac = v \cos \beta$
This denotes the velocity of the ship
towards the North, & to find it to
the East it would be multiplied into
the sine instead of cosine.

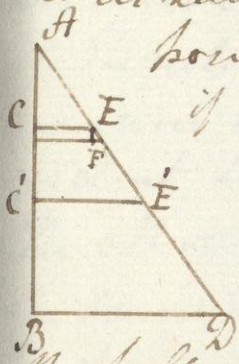
only different states of the same body.

(53 Art) We now declare the same Equations as in the Art. 50 & 51 $\dot{S} = \dot{U} \times \dot{S}$, $\dot{U} = \frac{\dot{S}}{\dot{S}} \times \dot{S} = \frac{\dot{S}}{\dot{U}}$, which may be geometrically expressed as before

(54 Art) The Mass, quantity of Matter, all signify the same thing but another letter $\dot{S}$ be introduced to express the quantity of Motion.

(55 Art) Every thing is in a state of continual change. If you have a Body falling to the ground its velocity will be increasing untill it reach it, now the small change that is made in the course of a second is its momentary increment, the mode of expressing this you will find laid down under this Art.

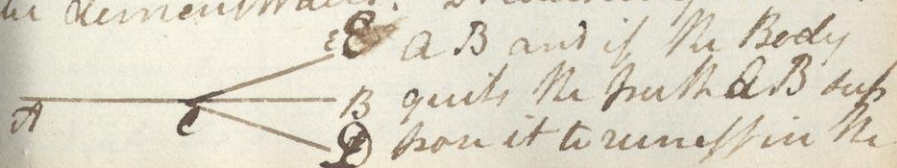
Let us now come to Geometry. Suppose a body falling from A to B if you draw a line A D making any angle with at D. The perpendiculars drawn from A, B upon A D will express the different velocities of the falling bodies. The momentary increment may be discovered by drawing a perpendicular indefinitely near CE



x This should be changed till we come to
its proper place in p. 89

upon a D, and letting fall the perpendicular
 colour from E upon it EF This will
 express the momentary increment
 of the space & momentum. Now in $\dot{S}$, $\dot{V}$ & $\dot{P}$. The velocity is in-
 creasing & the time is increasing
 but suppose for a very short space of
 time the velocity remain uniform, we
 shall have $\dot{S} = \dot{V} \dot{t}$ supposing $\dot{V} = 10$
 feet in a second, and the increment of
 $\dot{t} = \frac{1}{100}$ part of a second then $\dot{S} = 10 \times \frac{1}{100}$
 = $\frac{1}{10}$ of a foot This is the momentary
 increment of the space. see p. 90

(60 art)^x This is the first Law of Motion
 & was discovered by Kepler who thought
 his property in Bodies their in-
 ertice, we shall however call it their
 inactivity or inertia. The first part
 of the rule viz That they will forever
 remain at rest unless touched is too
 evident to require any illustration
 The other part That it will preserve
 the same rectilinear motion may thus
 be demonstrated. Draw any line as



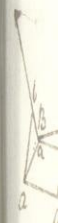
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in the direction CD Now draw the
line CE making $\angle BCE = \angle BCD$. Then
then C is the apex of a solid angle, which
is made up of $BCE, BCD, ACE, \& ACD$, there
is as much reason then that it should
run along CE, CB or CA (backwards) as that
it should run off at CD , here there is a "suffi-
cient reason" that it will continue in the
direction CB - (continued p. 89)

(57 Art) Suppose a body 1 lb moving
10 feet in a second, & one of 2 lb moving
at the same rate, you must multiply
the matter into the motion, suppose we
have a body of 10 lb moving as 5 & another
15 lb moving as 3 they are in proportion
as 50 : 45. quantity of matter does
not mean the bulk, as may be seen
in the case of cork & lead, it is from
the weight suppose the mass of two
bodies are M & M' the velocities V &
 V' the quantities of motion 20 & $2'$ then
 $2 : 2' :: MV : M'V'$

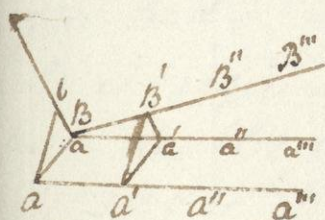
(58 Art) Suppose 2 ships sailing
in parallel lines they
set off from A & B with
precisely the same velocity
so that A should arrive at A' exactly

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in the same time ⁽⁹¹⁾ as B reaches B',
 &c. on, and let them arrive at each
 of these points in the same hour. They
 continue at the same distance, &
 their bearing is the same, you have
 then both relative & absolute motion if
 from the one you look at the other
 it will appear to you to be standing still
 as you both move in the same abso-
 lute space. We are always in relative
 motion from the motion of the Earth
 round its own axis, by which in our
 latitude we move at the rate of nearly
 500 mls. in an hour; & from its motion
 round the Sun—



Supposing 2 ships
 moving in the lines
 a'a' &c. & b.b'b' the one
 of them probably may
 be in sight of its mo-
 tion, must be the line in which the
 one sailing in the line B must go to
 as to seem to vary its bearing to A
 suppose the one sailing in the line A
 to continue uniformly, the other to
 go slower, now suppose the observer
 in A is unconscious of his motion
 what is the line in which he will think

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blowing him. Let ⁽⁹²⁾ space a to stand
still. Draw from B a line parallel
to $a a'$ making the line $B a' = a a'$. The
distance now is measured from a to B' .
The vessel will appear to go in the
line b —

600 Art.—(continued from p 89) If therefore
a body is once impelled forward it will
move continually with the same velocity
not considering at present the resistance
of the atmosphere or also the effect of
friction, which will afterwards be shown
to have very great effect over all moving
bodies. (a) Let us consider the leading
phenomena in Mech. Philosophy. The fall
ing of a body. The body whatever be
being it acquires in the first second
of time doubles it in the second, & so on
to the 3rd & 4th &c so that concerning a
body in 1 second of time to have ac-
quired a certain velocity, in the second
instant it will retain all it had at first
and gain as much again &c. There
is therefore in all Bodies a tendency
to come to rest. This is in my opinion
the strongest fact of opinion, that can be

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had, but it is not the only one. The
example of a Body suspended from
the ceiling of the Cabin of a Ship is another
good one, when the ship is at rest. When
the line is drawn it is to the uniform (i.e.
uniform motion) let drop from the body
suspended a stone or suspend a plumb
line and mark in the floor of the Cabin
the point in which it falls, now if the
ship is under way going with equal ve-
locity & quite uniform without motion
to the sides; the stone if again dropped from
the Body will fall upon the same point,
perpendicular below it, which shows
that the ship and every body in it have
a tendency to continue in the same straight
line. The disciples of Aristotle affirm
that it would fall behind the first men-
tioned mark, suppose therefore a stone
were let fall from the top of a Mast when
it arrives at the same spot on the deck
where the ship was in motion that it would
when at rest. Galileo tried this in
the Harbour of Pisa, he marked the
point it fell on when the ship was
at rest (the mast being a little inclined

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for the purpose) throwing out the
ship in motion when the stone was dropped
it was found to strike exactly the same
spot, thus effectually shutting the mouths
of these Philo-whims. If you throw a
body out of the side window of a Carri-
age when it is in motion, it will retain
the same motion it had when in the Car-
riage. If you stretch your hand over
the front window of a Carriage & let a
stone drop so as just to clear the body
of the Carriage, it will do the same when
the vehicle is in motion. In riding it
is a very difficult thing for the horseman
to be able to retain his seat when the
horse all of a sudden in a rapid pace
stops short. There is in Nature innumerable
very obvious examples of the fact that bodies,
if not put off by external causes, have
a great tendency to move in rectilinear
motion or in straight lines. When for
example we are sitting in a Carriage
we will find that in turning a corner
rapidly we are as it were impelled
forward in the former direction & are

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turned to the side. (95) This is obvious when
we are turning a corner when running
in which case we employ much caution
not to be thrown out into our former di-
rection. This however is chiefly observa-
ble in the running of Horses in a circle
when you may perceive the Horse's
side incline toward the center of the
circle to counteract this tendency to fly
off in rectilinear motion. I have seen them
may self incline fully 20° from the position
of a right angle (their position in rectilinear
motion) It is also well exemplified in
a string which moves in a circle and at
length one of the strings being let loose the
stone flies rapidly off at a tangent. To
let a stone off at an exact Tangent is
the great art of stringing, it therefore ap-
pears remarkable how expert some are
at this merely from habit for few understand
its principles. We have now a
means of knowing whether a body is
acted on by another or not let us now
consider Force —

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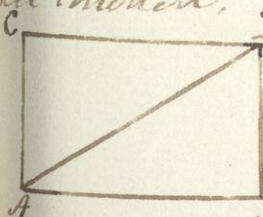
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61st = We have a certain idea of the word by knowing in him we put a body in motion we must enow a certain cause = 94, If in material object it cannot be perceived by our senses. This like Gravity a more object perceived by our intellect. If man were a more intellect without action or any kind of motion he could have no Idea of force, but having an Idea of motion he can also have one of force which is the cause of this motion. The forces here are represented by two line AB & CD when their



D motion is an in those lines and also when the forces are proportional to them that A B is when the force of the Body $A : C$ as the direction $AB : CD$ or the motion in $AB : CD$ — now follows

62nd = which is the chief Proposition in motion. If two forces be applied to

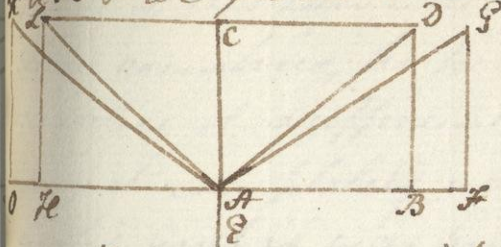


The Body at A the one driving it in the direction AB & the other in AC then it will B not only move in a direction between them but it will go in the diagonal AD — which may be proved by

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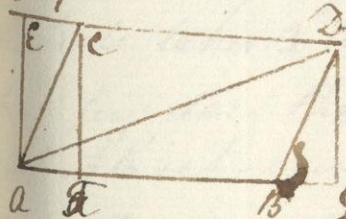
completing the Parallelogram having
 $Q.B$ & $A.C$ for its sides — In Wood's Mech.



suppose it to go
 faster from A to B
 than from A to C
 having marked F

as the increase of its velocity let fall
 the perpendicular $Q.F$, it has accelerated
 its motion by $B.F$, suppose there
 had been an equal force carrying it
 to L , $A.L$ being equal to $A.B$; it
 may therefore be shown that the same
 force acting at the same times may make
 it go 2 different ways and by which
 it accelerates its action by $B.F$ there
 way, this of course is absurd —

84 Art. From this figure it may be
 shown that the same
 is the case whatever the
 angle be a right angle
 or acute angle or even
 if there are three forces acting —



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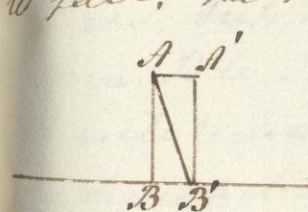


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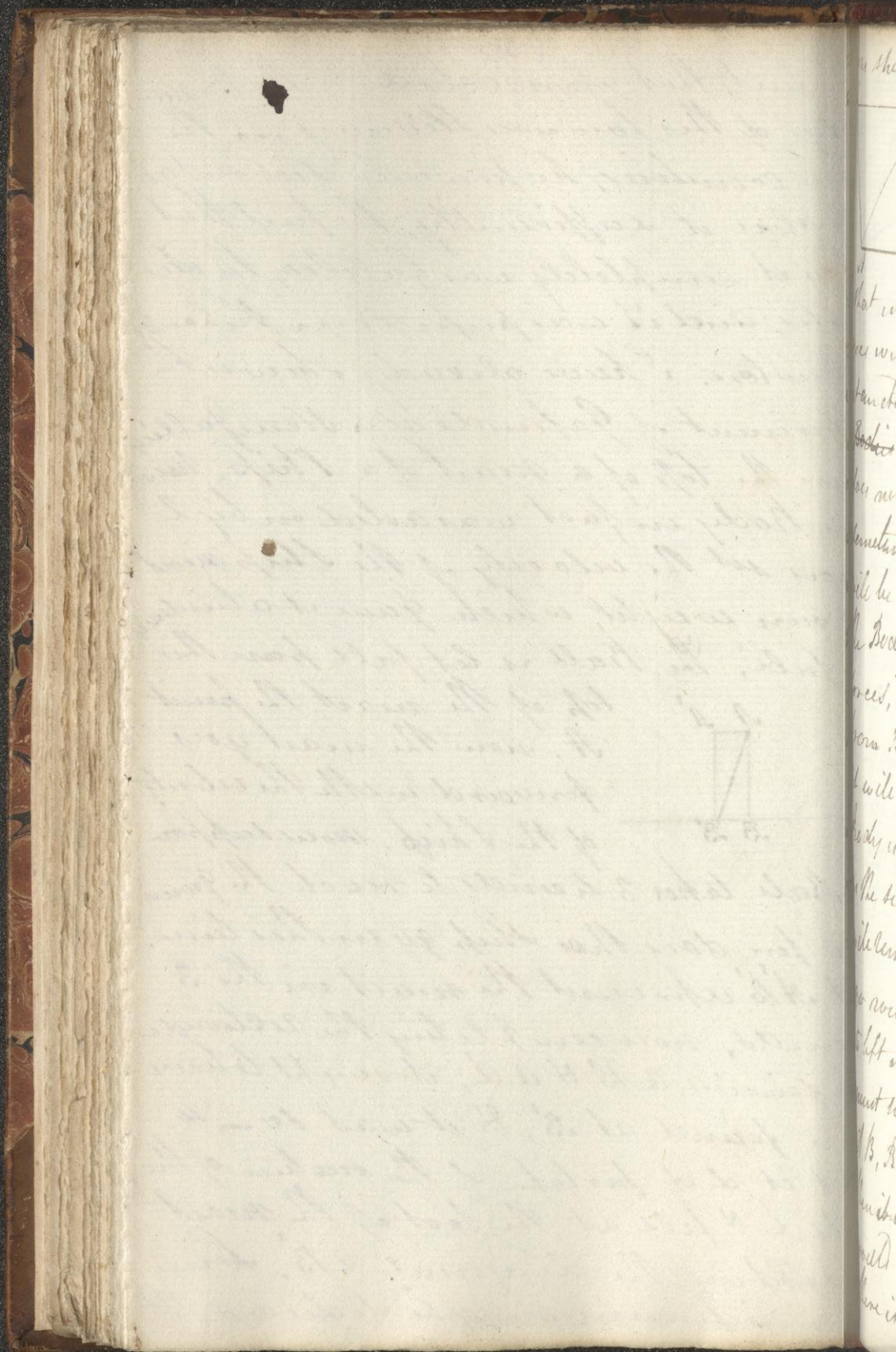
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The first that approached to the knowledge of this Law was Stevinus in the Law countries, he however did not generalize it sufficiently, the first that saw it completely was Galileo, the corrector, and it was perfected in the hands of Newton. I have already shown the experiment of Galileo of a stone falling from the top of a mast of a ship. Now this body in fact was acted on by 2 forces viz the velocity of the ship next its own weight, which gave it a tendency to fall. The Ball is let fall from the

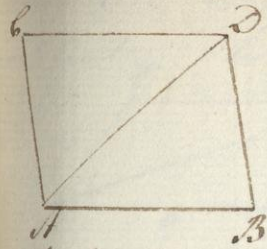


top of the mast the point A, now the mast goes forward with the velocity of the ship. now suppose

the Ball takes 3 seconds to reach the ground how far does the ship go in this time. Let A'B' represent the mast in the 3 seconds, now completing the rectangle by joining A B' & A A', it ought to have been found at B', & it was so — so that it did partake of the motion of the vessel & fell at the foot of the mast describing the diagonal AB'. Some more inferences may be deduced. 77



was shown in general that if there
be 2 forces acting at an
obtuse angle - complete
the Parallelogram, now
A D is the Diagonal, so



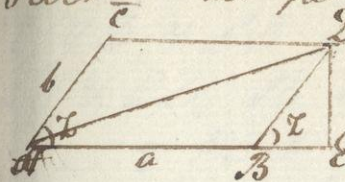
that in an obtuse angle the body
goes over a life line; for forces acting
at an obtuse $\angle$ tend to destroy one another
Bodies Force impelled on a body
does not always produce motion
sometimes it produces rest. The body
will be in Equilibrium for instance if
the Body be acted on by 2 opposite
forces, suppose it is acted on by a force
from D to A from C to A & from D to A
it will remain at rest. be that if a
body is acted upon by 3 forces that are
as the sides of any triangle whatever it
will remain at rest; you must have
go round the triangle from right
to left or from left to right. Thus you
must suppose the forces acting in
A B, B D, D A, not in A B, B D, A D for
then it would not remain at rest but
would be impelled in the line A D.
There is a Corollary which should be

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65 Art. — Let fall the perpendicular DE , then the square of $AD =$ the squares of AB, BD minus



the rectangle under AB, BE . $\therefore$ Radius

$$\text{or } 1 : \cos. Z :: b : b \cos Z, a^2 + b^2 =$$

$$2ab \cos Z; AD = \sqrt{a^2 + b^2 - 2ab \cos. Z}, \text{ or}$$

in other words, in the figure ABC

the sides AB, AC are represented by a

& b also the $\angle CAB$ with $= DBE$ by Z

then as $R : \cos. Z :: b : BE$ therefore

$$BE = \cos Z \times b. \therefore AC^2 = AB^2 + BE^2 + 2AB$$

$$\times BE \text{ then } AC^2 = a^2 + 2ab \times \cos Z + b^2$$

$$\text{taking square root } AC = \sqrt{a^2 + 2ab \times \cos Z + b^2}$$

which expresses the Diagonal — If

the $\angle A$ were obtuse the perpendicular

would fall within the line & the line

would become positive —

66 Art. — Now then we may employ

any triangle, as ABC , let

there be a point D

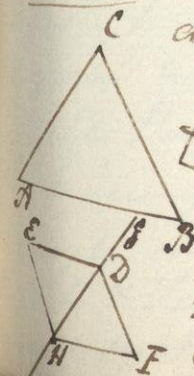
without the triangle

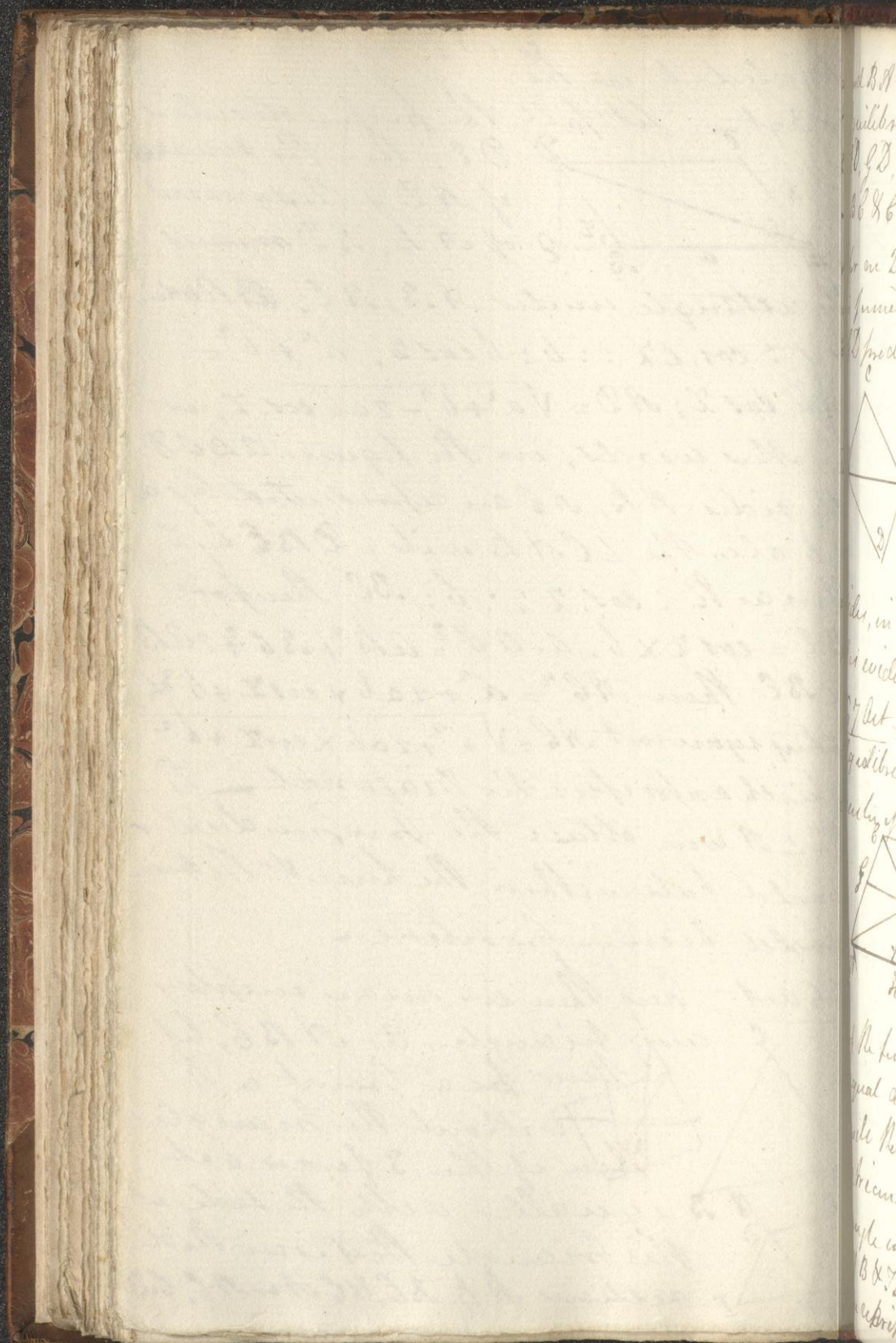
then if the 3 pass a L

equally with the sides of

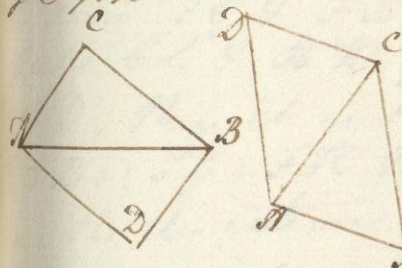
this triangle that is in the di

rections AB, BC, CA or $AB, CB,$





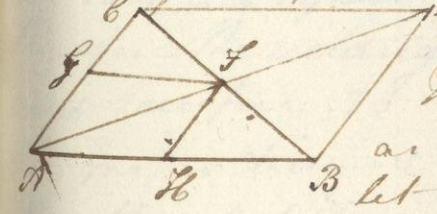
and BA then the body A is in Equilibrium. For to the point D draw $ED, GD, \& FD$ all parallel to AB $BC \& CD$, the body D is in equilibrium for on 2 $ED \& FD$ a parallelogram is formed of which the other force GD produced forms the diagonal



It may also be drawn from the 2 triangles without a separate point D . Thus draw ED parallel to the other

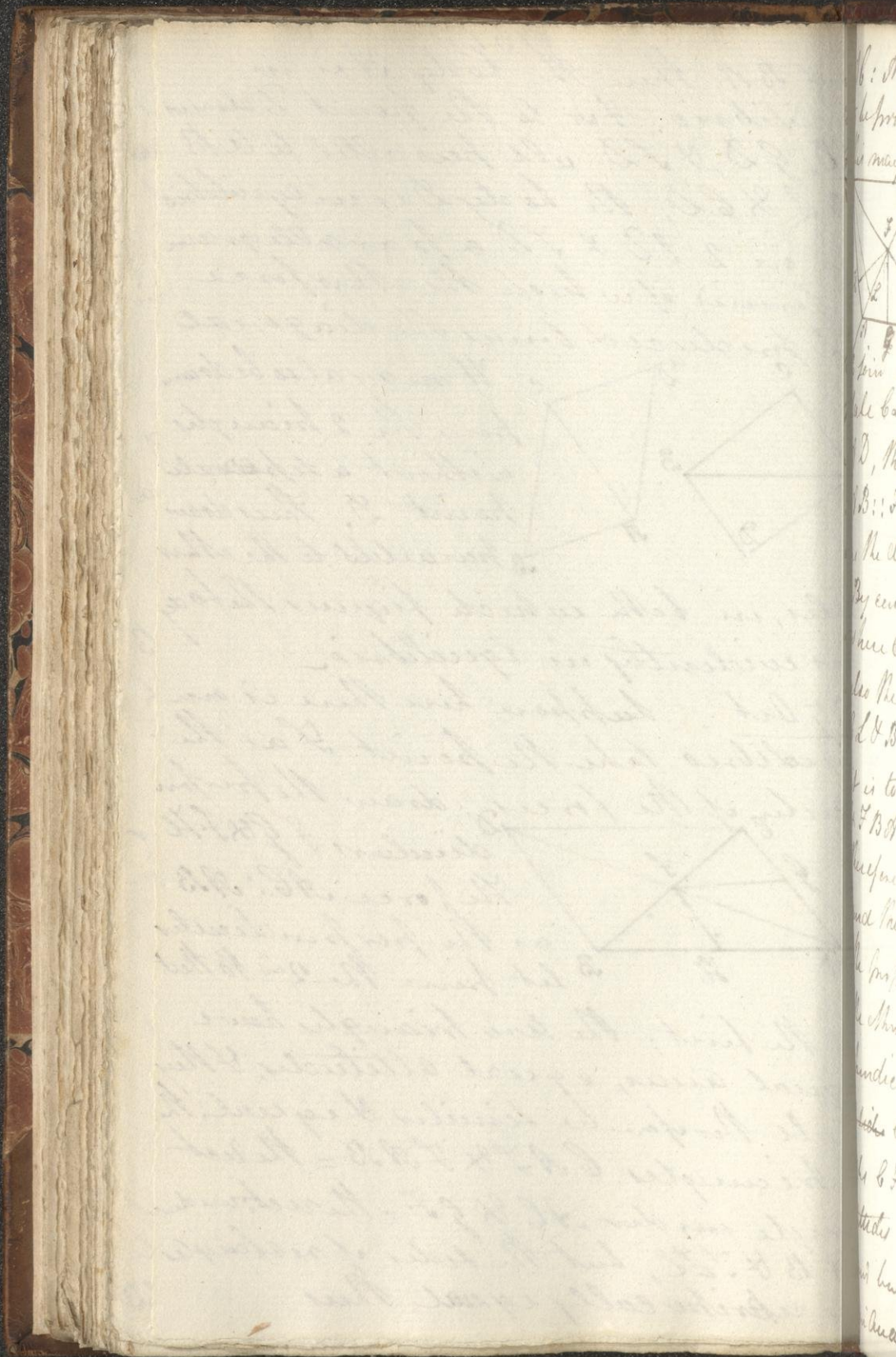
sides, in both which figures the body is evidently in Equilibrium.

67 Art. Suppose here there is an Equilibrium take the point F as the center of the forces, draw the perpendiculars $FG \& FH$

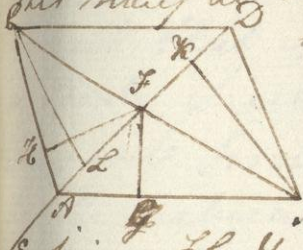


The force $AC:AB$ as the perpendicular let from the 2nd to that

of the first; the two triangles have equal areas, equal altitudes, & they will therefore be similar & equal; the 2 triangles $CAF \& FAB$ = the rect angle under $AC \& GF$ = the rect angle under $AB \& FH$, but the sides of rectangles are reciprocally equal thus



$AC : AB :: FG : FH$ which was
to be proved - ~~The 68 we shall suppose~~
This may be shewn in other words



Let any point F in the
direction DA be taken
from it, let fall the per-
pendiculars FG & FH
to BC & AD and from C & B let
fall CL & BK perpendiculars on
 AD , then it is to be proved that $AC :$
 $AB :: FG : FH$ that there are inversely
as the directions in which they fall.

By considering the extreme case
where C & B become C & B as
also the equality of the perpendiculars
 CL & BK after diverging from that
it is to show that the triangles CFA
& FBA are equal in area and that
therefore the rectangle $AC \times FH = AB \times FG$
and therefore $AC : AB :: FG : FH$
the perpendiculars being inversely as
the sines 2 sides. For since the per-
pendiculars being inversely as the sines
which CL & BK are equal the trian-
gles CFA & FBA are of the same al-
titudes & between the same parallels
and being on the same base are there-
fore equal in area from which the rest follows.

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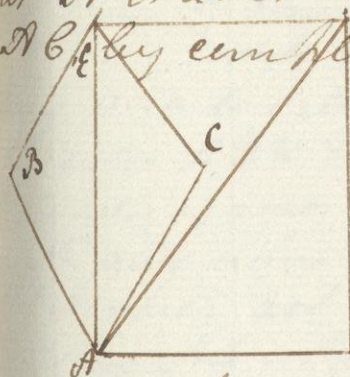
all this we are now considering
 & compound motion depends on an
 axiom which every one must certainly
 grant that if 2 equal forces act in
 a body directly opposite to each other
 they will produce no motion, rest will
 be the natural result—

68 Art— Let the point to which the
 forces are all directed be
 2 of them (any two) form
 the sides of a parallelo-
 gram of which the other
 is the diagonal if produced
 as in the figure the 3 forces
 being AB , AC & AE —

Draw the perpen-
 diculars GF , GH & GI
 to them 3 directions then
 it is to be proved that any
 of them perpendicular GH
 GF GH GI GF GH GI
 it falls on the force AB : DA . Now this
 depends on a simple proposition that if
 the heavy angle as BAC and if the sides
 at A perpendiculars be drawn as AD &
 AE then the $\angle BAC = \angle ADE$ for the $\angle$
 BAD & CAE are equal being right $\angle$
 by construction take any common part
 CAD then BAC remains equal to
 EAD the same is the case with the

triangle KLG , the side KH being
 perpendicular to the side DB of the
 $LDBA$ & KG to AB therefore the
 $HKG = DBA$. In the same manner in
 the $LGK = CAD$ that is to ADB the
 & consequently the remaining $\angle at G =$
 ADB then triangles are similar &
 then & their sides proportional that is
 $gk : KL :: AB : BD$ or $: CA$ so with
 all the rest. The perpendicular being
 proportional, to the force on which
 they fall.

69 Art- This is an extension of all
 we have now said. Suppose a body
 at A is acted on by the forces AB, AD
 AC by constructing the parallelogram



on AB & AC and draw-
 ing the diagonal AE

you may suppose it,
 is pulled by the 2 forces
 AE & AD so that it
 will in truth be acted
 on by a force pulling it from A to E .
 So that you may discover the course
 of a body however many forces act
 upon it. Take any Polygon as in
 the next figure $ABCE$, suppose
 there acts on a body at A five forces
 the first pulls it from A to B

The next from B to C & so on all round
 Then 5 forces acting in this
 manner will preserve it at
 rest, if there were only 4 of them
 acting on it, it would be impelled
 in the direction AE . There are but a few
 of collants I might have mentioned. A
 B might have been going in one plane
 BC in another & so on, but if they all
 return again to A , the body would re-
 main at rest. Thus we know that



if in the triangle ABC
 the forces act in the direction
 CA, B, BC & CB, A that A will
 be in Equilibrium, and here
 generalizing it much more
 add any 2 sides so as to form
 any quadrilateral figure $ABCD$, then
 the sides AD & DC equally act on AC
 & produce rest at A . The same happens
 with any number of sides as adding DE
 & EA which act with AD & DC with DE
 acts on AC as does also AD, BC & they
 all combine to produce rest at A . The
 same happens with any number of
 sides. This then is a very general pro-
 position that any number of forces
 proportional to their sides of the poly-
 gonal figure & parallel to them will
 produce rest —

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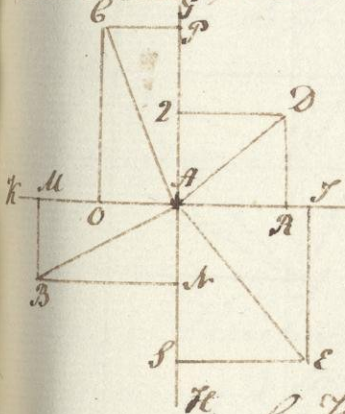
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Phew

25-10

70 Art — This is the most general mode of resolving forces when there are a number of them acting at once. — it is nothing new in principle, but it is convenient when the forces are rather more complicated. I draw any four forces



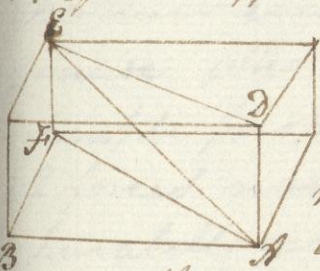
as BA, CA, DA, EA to A which is at rest, draw also GH & KL at right angles to each other; then from the extremities of the lines BA, CA, DA & EA let fall on the lines GH & KL the perpendiculars

$BH, BN, CO, CP, DQ, DK, ET, ES$. Then all the forces or sums of the opposite forces in the direction of each axis GH & KL be equal to one another thus $AP + AQ = AS + AH$ and $AT + AK = AN + AO$ &c. &c.

This is the most general proposition in all mechanics & its demonstration is much simplified by using algebraical expressions for the different forces & angles. Thus let the 4 forces be represented by F as often accounted for then are forces commencing at BA & let the angles regularly round be expressed

[illegible]

by the Greek Letters $\alpha \beta \gamma$ &c. Now then
 in the rectangle $B A S$, $B A : A S :: R :$
 $S \perp A B S$ is also $R : \cos. B A N :: B A :$
 $A N$ that is $R : \cos. B A N :: L : A N$
 then $A N = L \times \cos. \beta$ so also with all
 the rest substituting for $A N$, All the
 cos. of the different Greek characters —



When I say a force
 is directed in $A B$

you are to understand
 that I mean it is directed
 in the way I place the
 letters, therefore in this case it will
 be from A to B , suppose in this
 figure the forces are $A B$ & $A C$, then
 is another force directed upwards
 $A D$; now can construct the parallelepiped
 under these three then the body will
 be impelled from A to E , $A E$ will
 be the diagonal so that the 2 forces
 will be $A B$ & $A D$ so that it may
 easily be proved from what has al-
 ready been said that it can go in
 no other direction than in $A E$

Second Law of Motion

Section III^m of Part

The tendency of Bodies to move

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in straight line was first discovered by Galileo tho' it is said to have been also known before to Kepler who was cotemporary with that great man. The first person however who gave us a demonstration of the composition of motion was Stevinus a Flemish Engineer who showed us how that from the simple property of a body impelled by 2 forces moving in the diagonal of the parallelogram they form, is derived the whole Field of Dynamics.

(71) In order to understand action & reaction we always suppose the body acting & the body acted on. When motion is communicated by one body to another it loses as much itself estimated in the same direction.

By motion we must be understood to think of the product of the mass multiplied into the velocity let A & B be two bodies moving in the same direction. When A overtakes B as it is supposed to move with greater velocity it will communicate to B and will lose itself in that direction. Thus if

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A be moving twice as fast as B or
 as $2:1$ & if when it arrives at B it
 communicates to it $\frac{1}{2}$ of the quantity
 of motion, then it loses itself $\frac{1}{2}$. With
 this addition then B becomes $1\frac{1}{2}$ &
 A also becomes $1\frac{1}{2}$ having lost $\frac{1}{2}$, both
 equal to 3 as originally. If the bodies
 moving instead of moving towards
 one another in the same direction
 move towards each other in oppo-
 site directions then the quantity
 of motion gained by one body is just
 equal to what is gained by ~~the other~~^{the other}
 in the opposite direction, therefore
 when A & B meet if $A=2$ & $B=1$ & if
 A loses 1 & B gains it that will make
 $B=1$ in the opposite direction or both
 $=1$ in the direction of A to B. of this
 there are many examples in nature
 for instance with regard to a magnet
 and Iron if the magnet be 1 lb the Iron
 2 lb then the velocity of the Magnet
 will be inversely as its quantity of
 motion, that is it will move towards
 the Iron with double the velocity of
 the Iron - Such also is the case with the

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Earth and any Stone falling on its surface. The 2 bodies The Earth & Stone by their attraction approach each other from contrary directions, but from the immense size of the Earth that of Stone it is not perceptible but certainly happens as can be proved by Mathematical principles.

Under the same is Repulsion

which sometimes happens when 2 bodies repel each other, the same law applies to them. You must keep in mind that Action & Reaction only mean motion in one & in a different direction as in the instance of a Horse & Cart here the simple explanation is that the animal force overcomes the resistance of the Cart & thus it is conveyed along; if all the additional energy exerted by the Horse on the Cart were applied to himself alone it would make his motion equal to that he communicated to the Cart & to him self. Now there is a general remark I may make here, that this Lesson comprehends under it the whole of

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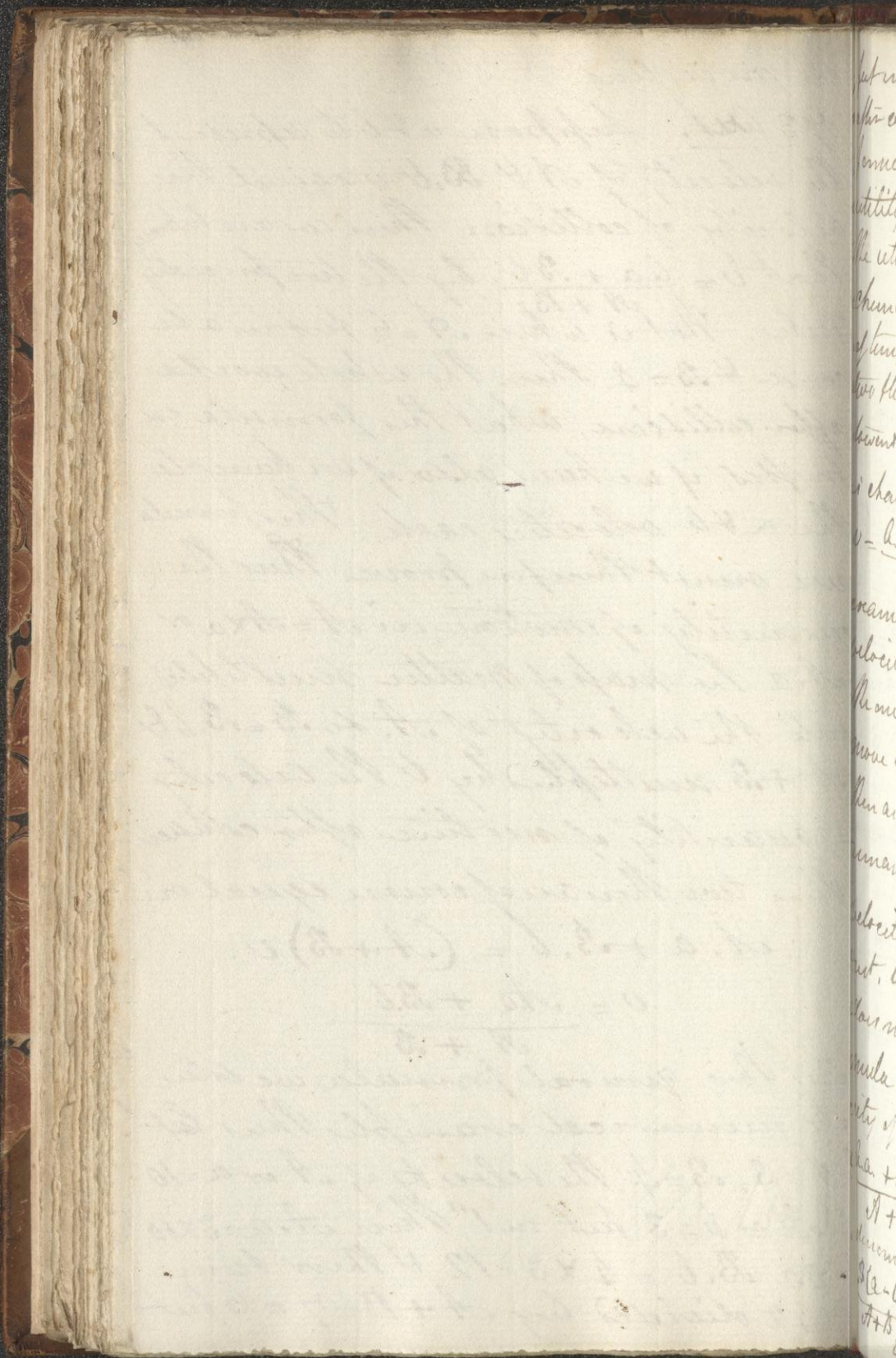
The preceding (111)

43 Ques. Suppose a & b to represent the velocity of A & B , & v equal the velocity of collision. Then we are to prove that $v = \frac{Aa + Bb}{A + B}$ by the two preceding rules. That is where $A = 6$ feet in a second & $B = 4$ then the whole would after collision, what this formula expresses, if we have also, if we have also the a & b velocities each. This formula we must therefore prove. Thus the quantity of motion in $A = A \times a$ or $A.a$ the mass of matter multiplied into the velocity of A . & $B = B.b$ & $A + B$ multiplied by v the velocity = quantity of motion after collision. These two then are of course equal viz

$$A.a + B.b = (A + B) v$$

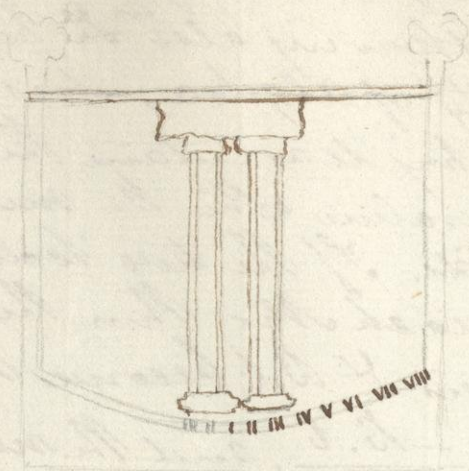
$$v = \frac{A.a + B.b}{A + B}$$

By this general formula we solve all numerical examples. Thus let $A = 3$, $B = 4$ the velocity of A or $a = 10$ of B or $b = 3$ feet in 1" then $A.a = 3 \times 10 = 30$ $B.b = 4 \times 3 = 12$ & their sum = 42 divided by $A + B = 7 = 6$ feet



put in a second ^{or} the velocity
after collision. This is remarkable
formula & is one of very general
utility showing also ⁱⁿ the high degree
the utility of algebra; it is used in
chemistry to ascertain the addition
of temperature of the mixture of
two fluids. If the two bodies move
towards each other then this formula
is changed & B.b becomes negative
 $v = \frac{A.a - B.b}{A+B}$, and the numerical

example is thus $\frac{30 - 12}{7} = \frac{18}{7} = 2\frac{4}{7}$
velocity after collision. If however
the one body as B is at rest whilst A
move towards it which forms a 3rd case
then as B & of course B.b = 0 then only
remains $v = \frac{A.a}{A+B}$ thus $\frac{30}{7} = 4\frac{2}{7}$ the
velocity after collision when B is at
rest. When the change produced
does not affect the total this for
mula will always hold. The velo-
city of A loses by collision is $a =$
 $\frac{A.a + B.b}{A+B}$ to bring them to a common
denominator $\frac{aA + aB - aA - Bb}{A+B} =$
 $\frac{B(a-b)}{A+B}$ This is the velocity the first body
loses, that the 2nd body gains may be seen
by comparison



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Thus the different motions were illustrated by Experiment, by a Apparatus, such as that represented opposite the 2 Bodies are suspended & after collision describe arcs which are as the chords, the same therefore occurring in a straight line. The balls have an end of Ivory or Steel, but the former is better, and to prevent the Elasticity their sides covered with putty — Now one of these Bodies being double of the other if I give the left an impulse as 4 that is take it up to the figure 4 marked on the index, & the greater as 2 then when they strike they will remain at rest. The this is negative $v = \frac{a - 2b}{3} = 0$ passes over the 76th ^{noticed afterwards by B. 15} Art and proceed to the 77th Art — Lead it may be noticed is one of the least elastic of the bodies it has however a degree of elasticity thus if you fire a Bullet against a stone wall it will not be found immediately at the foot of the wall, but at a small distance from it, when a Elastic body is struck from being a round it becomes flattened

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in a slight degree on both sides, the one cheek & the opposite to it. This with respect to an ivory Billiard Ball was noticed before p. I shall in a short time show you the reason that the opposite side is flattened; it restores itself again, & if it restores it self with such force as to drive it back as far as it fell originally it is said to be perfectly elastic, but this is seldom & indeed as far as experiment can go never so; for it is here is supposed to be so, but it cannot be subjected to experiment.

part -

~~Demonstrate~~ how it loses in being

$$\frac{B(a-b)}{A+B} \text{ and in motion } \frac{A B(a-b)}{A+B}$$

$$\text{Thus } a-b = A - \frac{A \cdot a + B \cdot b}{A+B} = \frac{A \cdot a + B \cdot a + A \cdot b}{A+B}$$

$$= \frac{B \cdot a - B \cdot b}{A+B} = \frac{B \cdot (a-b)}{A+B} = \text{velocity lost by } A$$

$$\text{and therefore that gained by } B = \frac{A(a-b)}{A+B}$$

$$\text{The motion lost by } A = \frac{A B(a-b)}{A+B}$$

is identically & therefore equal to what

gained by B. If they are to meet one

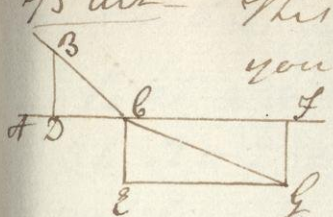
another then B becomes negative &

the signs are merely changed so the

$$\text{velocity gained or lost are } \frac{B(a+b)}{A+B}$$

$$\text{and } \frac{A(a+b)}{A+B}$$

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=a-2
A+3
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75 Art - This is the figure by which
 you may trace this, here

 C & G F form a parallelo
 gram. Let us now pro
 ceed to consider Boole's
 that one Elastic in which there comes
 to be a very great change.

76 Art. The A which was formerly =
 $\frac{B(a-b)}{A+B}$ now loses twice as much ve
 locity & is therefore = $\frac{2B(a-b)}{A+B}$. B on
 the contrary gains 2 and is therefore
 $\frac{2A(a-b)}{A+B}$.

78 Art - We shall now denote a & b as
 the velocities of A & B; but a' & b' their
 velocities after collision
 as in the line A B before
 us. The motion lost by A
 we know = $\frac{B(a-b)}{A+B}$ double it & take from
 it a & then $a - \frac{2B(a-b)}{A+B}$ which = a' veloci:
 after collision then solving the Equation
 $a' = a - \frac{2B(a-b)}{A+B} = a - \frac{2B.a - 2B.b}{A+B}$ This =
 $\frac{A.a + B.a - 2B.a + 2B.b}{A+B}$ from which we have
 $a' = \frac{A.a - B.a + 2B.b}{A+B}$ The same also with
 b except that its velocity is increased
 instead of diminished after collision

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$r = \frac{2A}{2}$

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B, b - A,

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Therefore $b' = \frac{B.b - A.b + 2A.a}{A+B}$ of this let

we take a numerical example let $A = 3b$, $B = 2$, $a = 5$, $b = 3$ what after recoil according to this last formula $\frac{3.5 - 2.5 + 2(2.3)}{2}$ or $\frac{15 - 10 + 12}{5} = \frac{17}{5} = 3\frac{2}{5} = A$ Now $B = \frac{6 - 9 + 30}{5} = \frac{27}{5} = 5\frac{2}{5}$ or $A = 3.48$ & $B = 5.4$.

The general law is thus demonstrated if $A = B$ then we have $a' = \frac{A.a - B.a + 2B.b}{A+B}$ &

$b' = \frac{B.b + A.b + 2A.a}{A+B}$ $a' = \frac{A.a - A.a + 2A.b}{2A}$

or $= \frac{2A.b}{2A} = b$ so also $b' = \frac{A.b - A.b + 2A.a}{2A}$

or $= \frac{2A.a}{2A} = a$

79 Art. — Thus then we commence saying

$\frac{B.b - A.b + 2A.a}{A+B} - \frac{A.a - B.a + 2B.b}{A+B}$ which =

$\frac{B.b - A.b + 2A.a - A.a + B.a - 2B.b}{A+B}$ this

= $\frac{B.b - A.b + 2A.a + B.a - A.a - 2B.b}{A+B} = \frac{B(a-b) + A(a-b)}{A+B} =$

$\frac{(A+B)(a-b)}{A+B} = a - b = a' + b'$ by hypothesis

$a + a' = b + b'$ Thus the velocities after collision are the same as before or the relative velocities are not changed.

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80 Art - This is deduced from the
last thus thus we know $A.a + B.b =$
 $A.a' + B.b'$ transposing $A.a - A.a' = B.b - B.b'$
therefore $A(a - a') = B(b - b')$ but $a - b = b' - a'$
we have $a + a' = b' + b$ therefore

$$A(a^2 + a'^2) = B(b'^2 + b^2)$$

$$Aa^2 + Aa'^2 = Bb'^2 + Bb^2$$

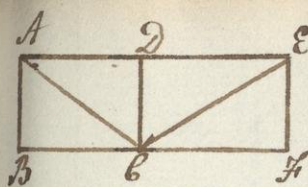
$$Aa^2 + Bb^2 = Bb'^2 + Aa'^2$$

$$\text{or } A.a^2 + B.b^2 = A.a'^2 + B.b'^2$$

This last part of the proposition has
been the cause of the dispute which
has divided mathematicians & the
astronomers. If it really be the case that
the single velocity is equal to the
square of the velocity. Thus in a canon
now suppose by a lb of powder a
ball be driven into a mound of Earth
a foot or say 3 feet whether there
were it changed with 2 lb the Ball
would pierce 6 feet or 9 the square
of 3 which latter is termed the velocity

82 Art - The angle of Incidence
will be equal to the angle of Reflec-
tion as represented in the figure over
leaf the Incident angle $AB.B =$

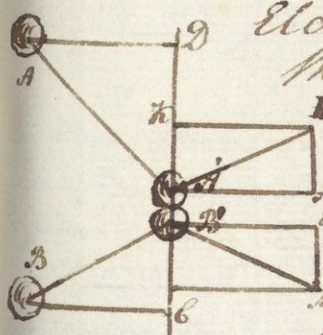
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(118)
reflected angle $\angle CEF$.
for if we draw CD per
pendicular to BF then
the forces AD & DB which

causes it to move in the diagonal
 AC being $=$ to AB & BC & these two
 $\angle F$ & $\angle C$ therefore $\angle F$ & $\angle C = AD$ & DB
and consequently make it move
in the diagonal CE of the equal
parallelogram $EFCD$ & therefore
 $ACB = \angle CEF$.

83 Art. Let A & B represent two



Elastic Bodies suppose
them to meet at $A'B'$
then the diagonals
 AC & BC will be
the paths after collision
= tion

84 Art. Thus the figure $A'B'$ is
the direction of each a & b their vel

A B
 a b
 a' b'
cities a' & b' after
collision. If they are
hard bodies A we know loses
 $B(a-b)$ but if they be in elastic

$A+B$
add $\frac{1}{2}$ & the whole is $\frac{3}{2}$ or $a - \frac{\frac{3}{2} \times B(a-b)}{A+B}$
 $= a'$ & as b loses $\frac{A(a-b)}{A+B}$ it becomes
the same way $b - \frac{\frac{3}{2} \times A(a-b)}{A+B} = b'$

x The following remark in addition to what has already been laid down in the 87 & 88 Articles will serve perhaps to impress the matter more fully—

From what has been already said you will perceive that time & space can be measured with great accuracy, this is not the case however with velocity, it we can only measure indirectly, you have seen that the product of the time multiplied into the velocity will give the space passed over so (in the figure opposite) if we draw lines parallel to A.B the space that will be passed over will be represented by the area

(119)
Sect. IV

of Motion equable acceleratly
or retardad —

This leads us to the interesting
consideration of Falling Bodies.

85 art. — Suppose the path of

the falling body to be $A.B$
since the space run over

being represented by $A.B$

is as the triangle $A.B.C$

& the space by another

$A.D$ is as $A.D.E$, then

spaces must be as the squares of

the Times $A.B, A.D$ for the similar

Triangles $A.B.C$ & $A.D.E$ are as the

squares of the homologous sides i.e

$A.B.C : A.D.E :: A.B^2 : A.D^2$ or $A.B : A.D$

$:: B.C : D.E$ the velocities & $A.B : B.C ::$

$A.D : D.E$

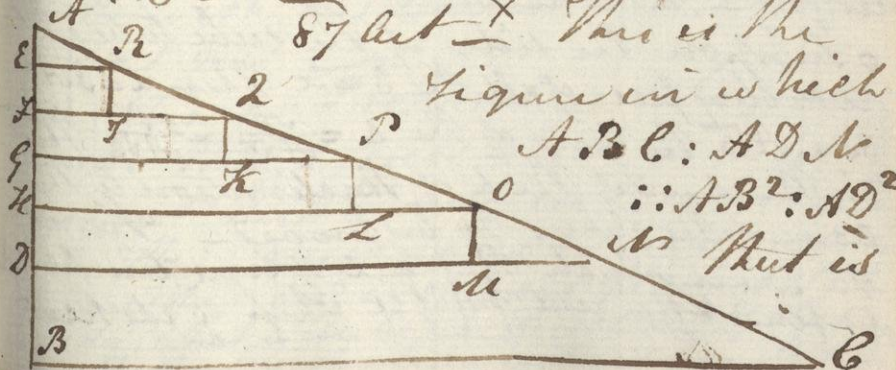
87 art. — This is the

figure in which

$A.B.C : A.D.E$

$:: A.B^2 : A.D^2$

as that is



of these small rectangles, now these
 space may be indefinitely small
 and of course the whole of them together
 will equal the whole triangle tho
 that we may substitute the area of
 the triangle; but similar triangles
 are to one another as the square of their
 homologous sides, therefore the space
 fallen thro' in one second, which is
 16 feet 1 inch, call it 16 ft. 16: Space
 passed thro' in t number of seconds
 $S :: 1^2 : t^2$ $S = t^2 \times 16$ now we have
 a step farther to go to introducing
 but this is very fully laid down in
 88 art -

x In order that there may be an equi-
 librium the 3 forces must be as the sides
 of a triangle thus suppose ABC any
 triangle then the first force must act
 in the direction AD & the
 other forces in lines
 parallel to the sides of the tri-
 angle - this to be proved -

o Suppose the side of the cube to be A the
 resulting force of all the 3 = x then $x^2 = 3A^2$
 $x = A\sqrt{3}$ The sine of the $\angle = \frac{A}{A\sqrt{3}} = \frac{1}{\sqrt{3}}$ This
 is the sine of the $\angle$ of inclination to the
 base of the cube. To be proved - This is
 the $\angle$ in which the sail of windmill should
 be fixed & the rudder of a ship to its keel

$S: S^1: S^2: S^3 \text{ } ^{(120)}$
 $S = h \times t$. now
 it is known that h which is the
 velocity of the descending body = $16\frac{1}{2}$
 feet in a second that is $S = h \times t^2 =$
 $16\frac{1}{2} \times 60^2$ if we wish to know the
 space descended in a minute then
 $60 \times 60 = 3600 \times 16\frac{1}{2} = 57,900$ ft in
 a minute & so with all three ex-
 amples always $S = 16\frac{1}{2} \times t^2$. The
 reverse of this happens when t the
 time in descending is required as $S =$
 $h \times t^2$, $t = \sqrt{\frac{S}{h}}$ which by Logarithms
 is a very short process.

I shall now give you 3 examples
 on what I have already said & expect
 that each Gentleman will give me
 in one of them solved by the end of the week
Example 1st Three forces as 4, 5, 8
 act on a body, what angle must they
 make with one another so as to keep the
 body at rest $\times$

2nd This is a Proposition to be proved.
 Prove that 3 forces which are as 2, 5, 8
 cannot keep a body in Equilibrium.

3rd Three equal forces at right angles to
 one another and on different planes act upon
 a body, what will be the direction of that
 force & what proportion will it bear to them.

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88 Art If instead of h we substitute
 g then $\frac{1}{2}g :: v^2 : 2g^2$ & $S = \frac{v^2 \times g}{2}$ or =
 $\frac{v^2}{2}$ & then $2gs = v^2$ & as $S = h \times \frac{v^2}{2g}$ then
 $\frac{2gs}{2g} = \frac{1}{2}gt^2$ from this $t^2 = \frac{2s}{g}$ or also
 $t = \sqrt{\frac{2s}{g}}$ which by Logarithms is a short
 process. From $v^2 = 2gs$ we have $v = \sqrt{2gs}$
 thus we have 3 formulas $v = \sqrt{2gs}$ $S =$
 $\frac{1}{2}gt^2$ & $t = \sqrt{\frac{2s}{g}}$ from which all the
 properties of falling bodies are deduced.
 Again, in other words $g = 32$ feet &
 2 seconds or $32/6$ $S = \frac{g}{2} \times t^2$ The first
 we investigated was $I^t v = gt$ $II^s = \frac{g}{2} \times t$
 Suppose we want to have the Theorem
 that will express the velocity into the
 space $v^2 = g^2 t^2$, $t^2 = \frac{v^2}{g^2}$ & another
 value of it is $t^2 = \frac{2s}{g}$ therefore $\frac{2s}{g} = \frac{v^2}{g^2} =$
 $2gs = v^2$ third general Law $III^v = \sqrt{2gs}$
 $IV^g = \frac{2s}{t^2}$ then 4 essential Theorems
 include the whole properties of falling
 bodies

Let us now consider the motion
 of bodies ascending instead of descending
 Let us examine the influence of
 gravity upon it. Very the retarding
 acts equally as in the ascent the
 same rate occurs different directed —

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(122)

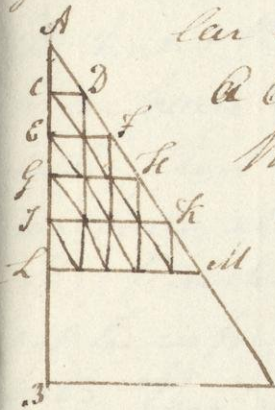
Suppose then that it ascends 1800
feet in a second. If we always take
32 from it or $\frac{1800}{32}$ This will give us
the time when it will be at rest or
turned back. This is entitled the Theory
of Retarded Motion.

90 Art— Suppose the constant ve-
locity equal c not v for that is varied
velocity. The motion then in any
number of seconds is demonstrated
by $g.t$ therefore $v = c - g.t$ when $t =$
 $g.t$ there will be no velocity, at the
end, time $t, v = 0$ i.e. $= \frac{c}{g}$ suppose
then that $c = 320$ feet in a second
this divided by $32 = 10$ seconds in
which time the velocity is completely
exhausted. It will fall back then
in the 10 seconds and when first
on the ground will possess the same
velocity with which it first set out up-
wards. Again— Let the body go over
a space in 1 second with its velocity
increasing it will in the 2nd second it
will go over a space = 2 ft it will
acquire as much more, therefore it
will be expressed thus $2 + 1 = 3$ In the
3rd it will go over $2 + 2 + 1 = 5$ for the
4th second $2 + 2 + 2 + 1 = 7$ & so on in all

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The odd numbers; now let us add
 them & we shall have the whole space
 passed over the $1^{st} \& 2^{nd} = 4$ & the third
 and we have 9, then 16 &c going
 thro' all the square numbers, & being
 the number of seconds $16 \times t^2 = s$ this
 is express'd in the second Law above.

Geometrically, let the perpendicular
 line denote the time then



& C D represent the space fall

thro' in a second, then the

second of time is repre

sented by the perpendicu

lar drawn to AB, we

have now the second

space divided into 3 triangles =

to one another & to the triangle ABC

the next equal 5, the next 9 &c

as expressed before algebraically.

This proposition agrees also then

plain the proposition in Euclid's simi

lar triangles are to one another as the

square of their homologous sides

This however tho' I did not

mention it you must remember

that the resistance of the air has like

wise a considerable effect as well as

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of Art -
take the
 $c = \sqrt{290}$
is the
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Sec 23 The
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Sec. 24
 $c - g t = 0$
 $c - t g = 2$
equation
c
sides & c
times t =
sides also

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The more gravity which we have
been considering

91 Art— Now to demonstrate this
take the 3rd formulae $v = \sqrt{2gs}$ therefore
 $c = \sqrt{2gs}$ and from this $s = \frac{c^2}{2g}$ This
is the height to which it must rise
and for it is that from which it must
descend to gain this velocity. Now

we know that $v = c - gt$ (90 Art) & $v = \sqrt{2gs}$
so we have $\sqrt{2gs} = c - gt$ square both
sides then $2gs = c^2 - 2cgt + g^2t^2$ then
we have also $g^2t^2 - 2cgt = 2gs - c^2$

By finishing which quadratic we
get the impression required—

Sec 23 This Lecture was completely
taken up by exhibiting & explaining
Mr Atwood's Machine for measuring
the descent of falling bodies. On this
a variety of experiments were made.

Sec. 24— 92 Art— After t the time
 $c - gt = v$ or i.e. $c - gt = v$ $c = tg$ & $t = \frac{c}{g}$
 $c - tg = 0$ then $s = \frac{c^2}{2g}$ — height tg
equate these two, then

$c - gt^2 = \frac{c^2}{2g} - h$ square both
sides & $c - gt = \sqrt{\frac{c^2}{2g} - 2gh}$ This equation
gives $t = \frac{c}{g} = \frac{1}{g} \sqrt{c^2 - 2gh}$ which formulae
will also give you the value of t &

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Section 3th

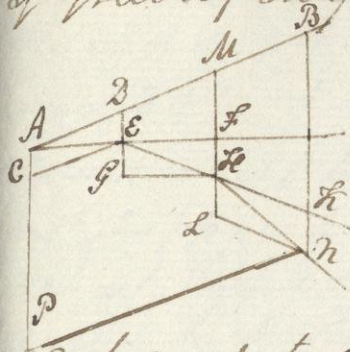
Thus we are not to consider any resistance of air but we are to consider a body projected forward but always obeying the impulse of gravity. Thus the Body is supposed to fly off at a Tangent as it were to a Parabola, which is the path it follows before reaching the ground. Now before proceeding to the particular consideration of this curious circumstance it will be proper to make you acquainted with some of the leading properties of this curve. The Body has the whole of its motion in the vertical line, it has no tendency therefore to go out of the plane of projection, this however cannot always be shown by experiment, in firing for instance the exact line in which the Shot goes cannot well be ascertained, nor can we be sure that the Shot & bowling balls are exactly spherical. We must first know the properties

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force & the Gravity, ⁽¹²⁸⁾ before we can be
able to ascertain the effect of the Air.
let us suppose at first that the force
of Gravity only acts at intervals. Sup



pose there is a body at
A, a cannon Ball fired in
the direction A.B let
A represent the force
of Gravity & A.C the
power of that force in

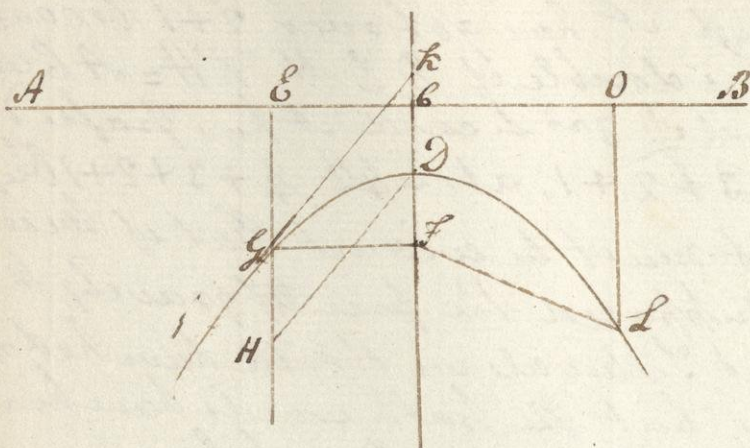
a second to carry it downwards, in
the same time (a second) that the powder
carries the Ball thro' A.D it will gain
the diagonal of the parallelogram
described under them viz A.E, & at the
end of the first second it will be
found at E, now at the beginning of
the second second the power of gravity
acting the same it will draw it down
in the direction E.G, & the powder will
carry thro' E.F, therefore it will gain
the diagonal described under them viz
E.H & at the end of the 3^d second it will
be found at H. In the fourth second its
path will be H.N and so on till
it reaches the ground. Suppose we
produce the lines A.C & A.D to B
all in the line of Projection, then

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$A D : D M :: A E : E F$ at the time
 it has reached H , at the end of the 2nd
 second it has got over $2+1$ because
 $M F$ is double of $D E$ & $F H = A C$ at
 the end of 3rd second it has passed
 over $3+2+1$, at the 4th $4+3+2+1$ &c.
 Now it must be evident that if we had
 not supposed the force of gravity to
 act at Intervals we should have had no
 angles, but the path would have been
 a curve forming a Parabola.

Sec. 25—Applying still to the same
 Figure joining $N P$, then the property
 of the Parabola is this that $A C : A P^2$
 $:: C E^2 : N P^2$. $A C$ is the descension one
 second so that it is equal to $\frac{g}{2}$ &
 the Initial velocity $= c$ & substituting
 x for $A P$ & y for $N P$ we have $\frac{g}{2} : x^2 ::$
 $c^2 : y^2$ convert this into an Equation
 & find the value of y^2 the $\frac{c^2 \times 2}{g} \times x^2 = y^2$
 c^2 is a fixed quantity—Now this is
 the Equation belonging to the Parabola.
 In the Ancient Geometrical
 books we find that the properties
 of the Parabola were pretty well
 known.



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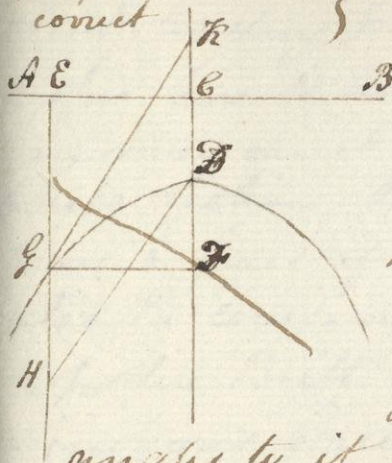
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The parabola not
correct



Let me now direct your
attention to a few of
the leading properties
of the Parabola. Sup-
pose the straight line
AB is indefinitely ex-
tended, & another line
as CD is drawn at right

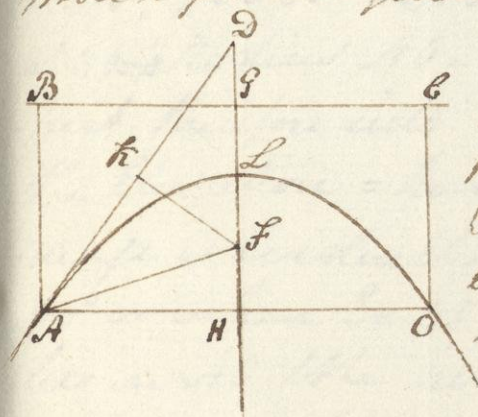
angles to it, in this line take any
point as F, then any point equally
distant from F the Focus & the direct-
rix AB is a point in the Parabola.
Thus G F is equal to GE & F L to L O &
in short any number of lines, thus
then the curve is determined. Any straight
line as EH parallel to the axis is called
a Diameter to the curve. CD the axis,
D the vertex of the Parabola, G H a Tan-
gent to it, CD the Parameter of the
curve, & FD the Abscissa; EG & GH are
the Parameter & Abscissa of the diameter
EGH, HD which is parallel to the tangent
is the ordinate to EGH, KF the subtan-
gent. The great property is that $HD^2 =$
 $GH \times 4 EG$ that is if $HD = y$, $GH = x$, $EG = p$

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Then we have $4p \times x = y^2$ & $y = \sqrt{4px}$ the
 great leading property. It may be
 proper here to notice some of the books
 you may direct your attention to in
 Conic Sections, there is Vince's Con. Sec.
 being a part of the Cambridge course.
 also the course in the Edinburgh Ency-
 clopædia Britt. by Wallace of Morham.
 Simpons Conic Sections but rather
 modern for a beginner — 95 Art —



Let us now trace
 this property by
 knowing the Impetus
 & direction & angle of
 elevation let us trace
 the Curve. Draw the
 horizontal line AC

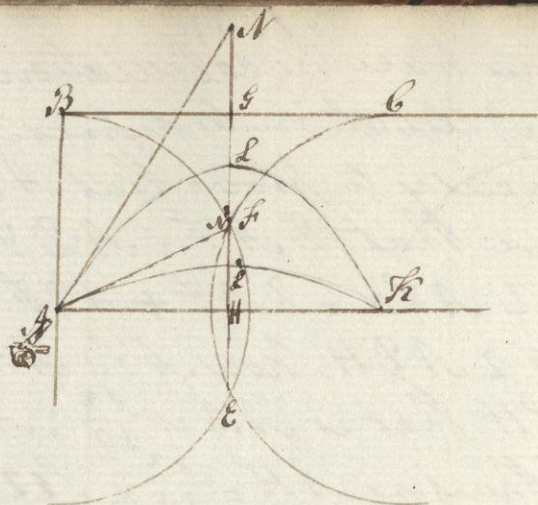
& AB perpendicular to it, being equal to
 the impetus or $\frac{c^2}{2g}$. draw AD. Make the
 $\angle DAF = \angle DAB$ & you thus get the focus
 F; bisect FG & you get the vertex L.
 The body then passes thro' L & O which
 is a principal to be attended to in
 Engineering, a body thus projected
 describes a Parabola, AC is the horizon-
 tal that it has gone when it falls at O.



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now let us trace the calculations. Let
 D A H L of Elevation be represented by
 E . It is easy to prove that $A F = F D$
 Therefore that $D A F = A D F$ & as the
 exterior $\angle A F H = D A F + A D F$ it becomes
 equal to $2 A D H$. Now $A F : A H :: \text{Rad.} :$
 $\angle A F H$ That is $A B$ or $\frac{c^2}{2g} : A H :: 1 :$
 $2 \angle E$ Therefore $A H = \frac{c^2}{2g} \times 2 \angle E$ & the
 double of it viz $A O = \frac{c^2}{2g} \times 2 \angle E$. If then
 $E = 15^\circ$, $2 E = 30^\circ$ & $A O = \frac{c^2}{2g} \times 2 \angle E$ but sine
 of $30 = \frac{1}{2}$ Radius $A O = \frac{c^2}{2g}$ simply. The true
 but therefore into the Sine of twice
 the Elevation = horizontal range. The
 range is evidently greater when $2 E =$
 90° or when $E = 45^\circ$ here the Focus
 lies in $A O$ & the horizontal range is
 the greatest.

Sec 26 Let us now consider what
 in gunnery is termed point blank.
 That is let us discover how we may
 cause the Ball just to strike R.
 Then then in the first place we know
 the properties viz that $B G$ is the directrix
 or a line parallel to $A K$ & that $A K$
 are both points in the Parabola

[illegible]

see the opposite side

Now then we find

the focus by describing
from A & K with AB
as a Radius two circles
their intersection without

is the Focus, Bisect

LG & L is the vertex. Make

LA = LH & will be the point

to which the Tangent at

or the direction of the Elevation.

Then then we find AA or the L

of Elevation AAH, at this angle then

the Gun is fixed & as it will move in

the parabola ALK it will in its

course strike K. Then an always shown

2 parabolas & the second AK represents

the lower one this will be seen better by

why— The Guns employed for these

various elevations are Howitzers as

they may be elevated to any & what

ever—

The greatest altitude of the

Howitzer is $\frac{c^2}{2g} \cdot \sin^2 \theta$ as will be in

immediately shown. Before showing

this however I may mention of

striking K when it is not in the same

plane as the gun.

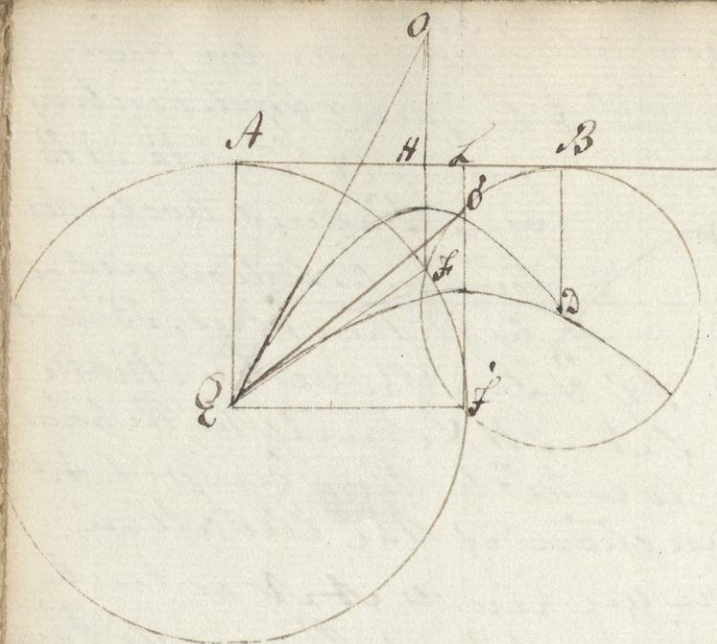
Let the gun be at A & the target at K.

Let the gun be elevated to an angle θ with the horizontal.

Let the target be at a distance R from the gun.

Let the target be at a height h from the ground.

Let the target be at a distance R from the gun.

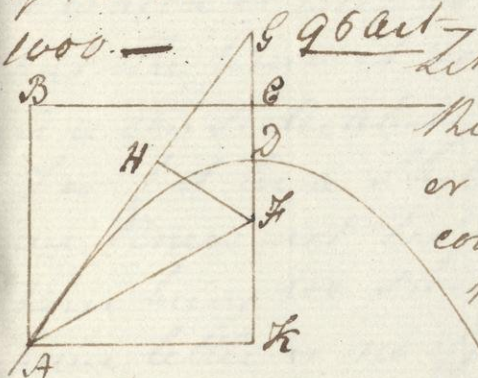


horizontal plane, as if it were a
 lower line. The charge of powder
 being given, to discharge from the
 point E a piece so as to strike
 the object at D. Describe the circle
 from A. From D at full the per-
 pendicular D.B upon the given
 direction the focus of every parabola
 passing thro' D must be in the
 circumference of a circle which has
 D for its centre & D.B for a radius.
 Now there are 2 foci that will an-
 swer, that is that both pass thro' E & D
 now describe these parabolas draw
 the perpendiculars FH & FL, join
 FE, & bisect the $\angle AEF$ by EO this
 is the elevation from principles al-
 ready established. Having at full
 the perpendicular FL & drawn
 EF, which is a line drawn to the
 focus, bisect the $\angle AEF$ by EO we
 have the other elevation which will
 strike the given point & the last being
 the lowest it is always the one to be
 chosen as it has less influence from the air.

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I shall here present⁽¹³³⁾ an exercise
which is connected with the subject
immediately before us

Exercise Suppose a Body to fall from the height of 1000 ft. above the surface how many seconds will it require for the descent, & what will be the descent of the body at the end of the 1, 2, 3 &c second & so on to the 1000. — § 96 art 7 *It is now convenient*



Let us now compute
the greatest altitude
or hD , if then we can
compute hG we have
the great altitude
of the ramp hD .

for it is equal to the $\frac{1}{2}$ of it. Now
 $GFH = E$ the elevation, for compare
the triangles AGH & HFG the $\angle H = R$
be right angles the $\angle G$ common there
fore there remains $HFG = GAH$ or $= E$
In the triangle HFG the Rad: SE :
 FG : GH but FG being $= AF$ or AB =
 $\frac{c^2}{2g}$ i.e. as $1 : SE :: \frac{c^2}{2g} : GH$ then $GH =$
 $\frac{c^2}{2g} \times SE$ i.e. double or $AF = \frac{c^2}{g} \times SE$
from this then calculate HG .

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now as Rad: S.E. :: AG: GK or as
 $1: S.E. :: \frac{c^2}{g} \times S.E.: GK$ so $GK = \frac{c^2}{2g} \times S.E.$
 Then the $\frac{1}{2}$ of it or $LD = \frac{c^2}{2g} \times S.E.$ and
 as $\frac{c^2}{2g} = AB$ or impetus Then we may
 say that Impetus into the square of
 the Line of Elevation = the utmost
 range of the shot above the level of the
 ground. This then is the utmost height
 to which it will ascend in its range;
 but the time it occupies in that range
 is a consideration of much importance
 For if it be a Shell which is fired if
 we knew not the time it might either
 prove being too slow burst in the air &
 have little or no effect; or prove being
 too soon might lie sometime on the
 ground & thus have its former extinguish
 before it burst. One would at first
 conceive this a most difficult calcu-
 lation but somewhat has just been
 explained it comes to be very easy.
 we know that $AG = \frac{c^2}{g} \times S.E.$ & then
 $t = \frac{c}{g} \times S.E.$ this is only the time from
 A: D the whole time of the range is
 double of this or $\frac{2c}{g} \times S.E.$ if then $c = 30$
 $t = \frac{c}{g}$ the utmost range is somewhat

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about 30. or 40". (335) This is the great prin-
cipal of Shrapnel shells which burst
just before reaching the ground & dis-
charge bullets & grape shot in every
direction. This then altogether is a beau-
tiful example of the application of
Geometry. They may be found ex-
emplified pretty nearly in some
of the objects in Nature. But it must
be remembered that during the whole
of what has been said the body has
been supposed to have been projected
in a vacuum. In the Atmosphere
a Canon ball never moves in a com-
plete parabola, & sometimes deviates
very much indeed from it.

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Let us now proceed to consider
the motion of bodies not free to obey
the impulse given them, this forms
the branch which is called

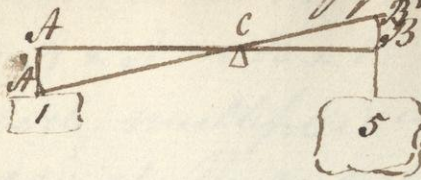
Mechanics

Sec. 1st

Center of Gravity of any body
is that point upon which the
body or system acted upon by
the force of gravity will ^{balance} ~~become~~
itself in all positions. If you
take a sphere composed of homo-
geneous matter it is evident the center
of gravity in it is the center of
magnitude, & it is so in all regular
figures as a pentagonal prism &c.
supposing it to be perfectly homo-
geneous it requires nothing more
than the sufficient reason to
prove this truth. We have how-
ever more commonly to do with
irregular bodies. Here for instance
is a sphere denoted by unity & $\frac{1}{2}$
another denoted by 5 when is

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their center of gravity⁽³⁾. I must
 first remind you
 of the general principle
 that no body commu-



nicates motion to another, which is not
 subtracted from its own; so that if it
 gives the whole of its ^{motion} velocity to another
 without its losing entirely its own ve-
 locity - Suppose we have at the end
 of this inflexible rod AB two bodies
 attached, now where is the point where
 they will remain in equilibrium, sup-
 pose C . Then if that is the point we
 shall have an $AC : CB :: B : A$. Then
 they be balanced, multiplying the ex-
 tremes I mean then $AC \times A = CB \times B$.
 They are therefore at rest but let us
 suppose them in motion, one must
 descend & the other ascend, let A de-
 scend, the lever then takes a new
 position which is represented by
 $A'B'$, B rises to B' , & A descends to A'
 each of them describing a certain
 arch, we have therefore as the arch
 $AA' : BB' :: B : A$, but the arch AA'
 is the velocity of A therefore the

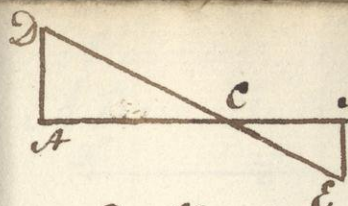


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$v.A : v.B :: B : A$ consequently the
 $v.A \times A = v.B \times B$ but the velocity of a
 body multiplied into the body itself
 equals the quantity of motion so
 that in the above equation it has
 communicated to B as much mo-
 tion as it had itself & still keeps in
 motion, which is an impossibility
 therefore they must remain at rest
 the fulcrum C therefore is their cen-
 ter of Gravity it divides the bodies in
 the reciprocal ratio of the bodies them-
 selves - If $A = 3$ & $B = 7$ we must di-
 vide the rod in the ratio of $3 : 7$. re-
 present the distance AC by a & the
 the whole distance AB by x then
 $Bb = a - x$ then 3 or value of $a - 3x$
 $= 7a - 7x$ then $10x = 7a$ & $x = \frac{7a}{10}$ so
 that the larger part equals the
 larger body multiplied into the
 distance & divided by the sum
 of the bodies - It may easily be
 shown also by Geometry for
 from the point A draw the perpendicular
 line to

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$AD = \frac{3}{4}$ & from B

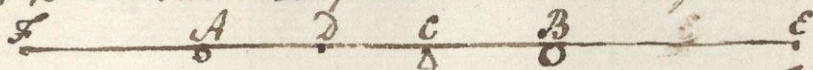
The perpendicular B

$E = 3$ then join them

and the line when it intersects AB
passes thro' the center of Gravity. This
may be easily proved by Geometry.
Likewise, because a body rests when
its center of Gravity is supported, & not
else; we hence derive another
easy method of finding the center
mechanically. For if the body be laid
on the edge of a prism, or over one
side of a table resting on the edge, &
moved backward & forward till it
rests, or balance itself; then is the cen-
ter of gravity just over the line of the
edge. And if the body be then shifted
in another position, & balanced on
the edge again, or any number of times.
These lines will also pass by the center
of Gravity; & consequently the inter-
section of them will give the center
itself — We are indebted to that great
man Archimedes for the 1st steps towards
real Mechanical Science it is the

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following. Having divided the line
 AB in the reciprocal ratio of the



bodies. Now we may conceive the largest body at B formed into a cylinder in AB cut off a part = to AB & produce it to E making $BE = BD$ now the largest is formed into a cylinder of which the length is DE , produce AD backwards to F making $AF = AD$ now at is a smaller body it may be formed into a cylinder of the length of D & having the same base so that in fact we may have but one cylinder, but the point C is the center of this long cylinder, the line $BD = BE$ so that $CB =$ the given line AB . In the same manner the line $FC = AB$ so that C is the center of this long cylinder; This is an extremely simple & unobtrusive ingenious proof & considering the age in which it was discovered is altogether astonishing—
 In Wood Mechanics p 52. Sec 73—
 Suppose any line as AB to which are attached the heavy bodies & let them

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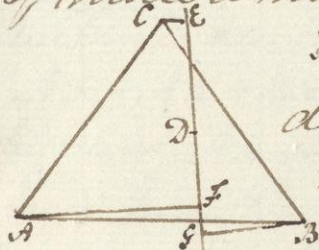
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141
 Let them be in equilibrium at C, sup
 $A \quad \underset{\Delta}{E} \quad B \quad B'$ pose we increase
 the distance B to B' , it would require
 twice the power to put it in Equilibrium
 if remove three times as far from A then
 it would require thrice the power &c
 so that the power of a body to produce
 motion is its distance from the centre
 of motion multiplied into its weight.



If from C AD.B perpen
 diculars be let fall from
 them on the line EDF
 the middle point is
 the centre of Gravity -

107 Art. The word momentum is
 just the product of the force or weight
 multiplied into the distance, two
 bodies therefore are in equilibrium when
 their momentums are equal - If
 the body $A \times AB = D \times DE + E \times EC + B \times BE$

110 Art. - If there be a number of
 Bodies of various magnitudes placed
 in the same straight line as the fig
 H A B C D E F G H
 suppose the centre
 of Gravity G is
 found take a point H beyond them all

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Let $AH = a$, $BH = b$, $CH = c$ $DH = d$
 now AG is what we want call it x .
 then $HG = x - a$ then multiplying Ax
 $x - a$ gives the momentum of A $BG =$
 $x - b$ & the momentum of $B = B \times x - b$
 then add these. $CG = x - c$ & the mo-
 mentum of C is $C \times x - c$ & the mom-
 of D is $D \times d - x$ & this is the sum of
 the momentums, now the one sum
 will be equal to the other

$Ax - Aa + Bx - Bb + Cx - Cc + Dd - Dx$
 by trans. $Ax + Bx + Cx + Dx = Aa + Bb + Cc + Dd$
 now here the coefficient x is x into the sum
 of the whole therefore $x(A + B + C + D) = Aa + Bb + Cc + Dd$
 $x = \frac{Aa + Bb + Cc + Dd}{A + B + C + D}$

The momenta divided by each of the
 Bodies is the formula for finding
 The centre of gravity — Numerically

$H \quad \begin{array}{ccccccc} A & B & C & D & & & \\ & & \Delta & & & & \end{array}$ we need not take
 the whole bodies for

we take $A B C$ & represent the sum
 by 4 B by 6 & C by 10, the distance
 $AA = 1$ the distance $HB = 3$, $HC = 5$ now

$$\frac{4 + 18 + 50}{20} = \frac{72}{20} = \frac{7.2}{.2} = 3.6$$

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110 Art- Thus if there be 3 bodies A
B & C. If A & B be united

& at D their centre of Grav;
D & C be united then
the centre of Gravity of DC
is evidently the centre of Gravity
of the whole 3 points & E is the
point which if supported the 3
bodies A B & C will be at rest.

112 Art- Suppose there be a
plane at A B C D. If G
be the centre of Gravity
& K H any line drawn
at the end of which K
the plane is to be sup-
ported then the plane

will not be at rest till the point
G coincide with the line K H. This
is well exemplified by experiment
take a wooden parallelogram plane
suspend it by a string at any point
in either of the sides. if also from
this point a plummet be suspended
the centre of Gravity which is sup-
ported, previously known, will coincide
with this last line. If the plane be
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it is commonly termed ⁽¹⁴⁴⁾ Stable but if
it preserve its centre of Grav. by standing
then it is termed unstable gravity.

The same principle applies to this
figure on the inclined plane.



If a perpendicular, drawn
from the centre of Gravity, fall just on
the extremity of the base; the body may

stand, but the least force
will cause it to fall that
way. And the nearer the

perpendicular is to any side, or
the narrower the base is, the easier it
will be made to fall, because the cen-
tre of gravity has the less height to
rise; which is the reason a globe is

made to roll on a smooth plane by
very the least force. Hence if the cen-
tre of gravity of a body be supported,
as in Fig. 2. for the line ca falls within
in the base ad , the whole body is sup-
ported — neither will it fall

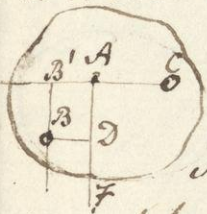


when I place it in the fig-
ure below where it is supported
by a piece of wood which rests
on a plane for then also the
centre of Gravity is supported —

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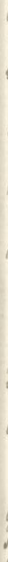


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By altering the center of gravity, by filling the hole A with lead you may even cause the cylinder to roll up an inclined plane.



Suppose this to represent any plane balanced about A. How are we to measure the weights B & C - This you know is done by measuring their distance from the horizontal line by perpendiculars drawn to that line. From B let fall a perpendicular BD on the horizontal line AF. From C another CE; now there will be an equilibrium if $B \times BD = C \times CE$ it would have the same effect as if the Body were supposed to be at B'. It is a mechanical thing in Mechanics to remember the proposition that nothing comes to rest unless its center of gravity be the highest or lowest possible in the construction of a. Bredie the center of gravity is the highest possible mean of a stone bridge

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This principle should be apply
more than it is in the construction
of Carriages, The cen: of Gravity should
be made much lower & particularly
in stage coaches but I shall
have opportunity of advancing this
more fully by & by - 114 Art -

To find the center of Gravity of a
number of bodies. Suppose $ABCD$
contain bodies in any plane
any how situated with
respect to each other, draw
the line EF as an axis
& let perpendiculars fall
from the bodies on it AG, BH, CK, DL .
we know the bodies we know the dis-
tances Suppose we have found the
center of Gravity of the line EF say O
then the center of Gravity will be in
the line OLL because the Momentum
on one side is equal to that on the other
The Momentum of B is represented by
 BH , & by AG &c, Now draw the ver-
tical line GH & let perpendiculars fall
from the different bodies
 DA, Aa, Bb, Cc then find its center of
Gravity P from P draw the straight
line PQ then PQ will be so situated

