§0.1. *The Translator's Introduction to Gregory's Optica Promota.*

We will not give a complete history of the short but productive academic life of James Gregory (1637 - 1675). Here we relate only some details relevant to the *Optica Promota* [1] itself. First, we note that each section in the translation consists of a collection of related theorems and problems, presented in their original order, prefixed by a synopsis, and followed by references and notes - to which the original Latin text is finally adjoined. It may be remarked that the amount of published material on James Gregory is disappointingly small, and most of that is not readily available. Thus, modern optics texts, even those which present some sort of cursory historical overview, usually omit Gregory altogether. It is hoped that anyone who succeeds in reading this translation and commentary will become convinced that Gregory did make the initial fundamental mental leap needed to elucidate image construction; also in his work will be found the beginnings of Huygens' Principle, as well as a number of the tricks used in producing ray diagrams, such as the use of auxiliary axes, etc. In this translator's opinion, the book is a wonderful piece of work, and the various parts of it eventually are orchestrated together in a masterful manner: indeed, the material is raised to a high level of completeness from very meagre beginnings, under the influence of a mind of amazing capabilities. The lack of appreciation of Gregory's achievements in optics may well lie with Gregory himself, as he did not 'spell out' his methods explicitly, but left his readers to ponder over the ray diagrams. Thus, previous recent commentaries on the *Promota*, such as the few pages in chapter VII of H.W.Turnbull's *Tercentenary Memorial Volume*[2], and Antoni Malet in his Princeton University doctoral thesis (1989)[3], do not bring out the significance of the ray diagrams. Whiteside was later to cast a desultory eye over the work, and to expand on its weaknesses rather than its strengths, which are obscured by Gregory's style of presentation. This impasse has been overcome by the present writer, and a version of the work is presented in translation with the diagrams explained in detail in the majority of cases, while others have been left for the reader following the lead given. Ours is the first generation liberated from much drudgery by the computer, and a drawing package has allowed the ray diagrams to be examined in an interactive way, to the point that they seem obvious and natural Also, by making use of the modern technique of applying ABCD transfer matrices, adapted here for lenses and mirrors with ellipsoidal or hyperbolic surfaces, a rigorous theory can be developed. Ray diagrams like all geometrical demonstrations suffer from the defect of presenting only one situation, whereas algebraic methods are quite general in application, although they do show what is going on with the light rays, which is probably why they still find a place in text books.

An interesting article by A.D.C. Simpson in the *Journal of the History of Astronomy*[4] sheds some light of its own on the origins of the *Optica Promota*, apart from what Gregory tells us himself in his preamble. From Simpson's researches we learn that the youthful Gregory who hailed from the northern climes of Aberdeen in Scotland was going off to do a grand tour of Europe, a popular activity for well-heeled young men in Britain at the time - though Gregory's tour was of a more serious academic nature than that of most young men of the time. During his London sojourn, he was to have his little book on optics published, on which he appears to have spent several years in the composition, and a start made on a mirror for his telescope. It was Gregory's chagrin while in London to discover that a work on optics, including refraction and reflection by

lenses and mirrors with conoidal surfaces, had already been published by Descartes as an illustration of his method of reasoning many years previously. Indeed, the law of refraction as we know it was first published in the *Dioptique* [5]in 1637 , and Descartes had applied the law to the ellipse and the hyperbola for rays parallel to the axis in much the same way as Gregory, in an effort to explain the imaging properties of lenses.

The modern reader may wonder at this lapse in scholarship, but one must recall these turbulent times - the Civil War in the 1640's had cast a long shadow over the academic world in Britain - in which the Gregory family had become embroiled (to the extent that Gregory's eldest brother was murdered in a feud), and the difficulty in obtaining books in what was then a remote part of the country. We may point out that the Anderson family, well-off merchants and influential in the N.E. of Scotland at the time, to whom James Gregory was maternally related, had already produced Alexander Anderson, an outstanding mathematician who became a professor of mathematics in Paris, and who edited the unpublished posthumous works of Vieta ~ 1617. It was possibly due to this great-uncle that the library at Aberdeen had the optics works used by Gregory[6]. We also learn from Simpson that copies of Mersenne's *Harmonica* and *Cogitata physico-mathematica* were acquired by the same library in 1635. The first of these works, although one of the first books on musical theory, also contained designs for reflecting telescopes originally due to Cavalieri. The interested person can access this information in an article by Arotti *Bonaventura Cavalieri, Marin Mersenne, and the Reflecting Telescope* in *Isis*[7]. Only in 1644 did Mersenne bring some order into his published works with the final version of his *Cogitata* and *Geometriae Universiae*, the latter containing some unpublished work by Warner and Hobbes on optics. These early ideas on reflecting telescope design used a concave mirror with a hole at the vertex, through which light passed to a further concave or convex mirror, and Gregory may have been aware of them via Mersenne - if he was interested in the theory of music! However, he may have felt that his own work was far superior - as he had produced working designs for mirrors and lenses. Also, the presence of Warner's work is of considerable interest, as he was present when Thomas Harriot first discovered the law of refraction around 1600, and thus his writings may show Harriot's influence: for example, the ray diagram demonstrating refraction presented by Warner is different from that developed by Descartes and subsequently used by Hobbes and Mersenne. It is of course a fruitless exercise to indulge in speculation at this late date.

Gregory fared even worse when an attempt was made to fabricate the reflecting telescope than with his book, which initially was beyond the craftsmanship of the time. Thus, all of Gregory's hopes were dashed. However, the seeds were sown: Newton produced a simplified version of the telescope, and a little later Robert Hooke succeeded in producing a reflecting telescope according to Gregory's design. To this day, the aspheric lenses and mirrors are still hard to make. Nevertheless, we are left with the ray diagrams, which portray imaging devices for paraxial rays (without spherical aberration). It will, however, greatly aid the reader's understanding and appreciation of Gregory's work, if we consider first the passage of rays through these surfaces from a modern point of view. This work is set out in the next section.

Notes & References for §0.1.

1. *Optica Promota seu abdita radiorum reflexorum & refractionum mysteria, geometrice enucleata; cui appendix, subtilissimorum astronomiae problematon resolutionem exhibens*. Autore Jacobo Gregorio, Aberdonensi. Londoni 1663.

2. *James Gregory Tercentenary Memorial Volume*. H.W. Turnbull. Bell (1939)

3. *Studies on James Gregorie* (1638 -1675). Antoni Malet. Princeton University doctoral thesis (1989).

4. *James Gregory and the reflecting telescope.* A.D.C. Simpson. *Journal of the History of Astronomy* (JHA), *xxiii* (1992), pp.77-92.

5. *Discourse on Method, Optics, Geometry, and Meteorology* Rene Descartes. An English translation and forward by Paul J. Olscamp. The Library of Liberal Arts. Bobbs-Merrill Co. (1965).

6. In ref. 4, Simpson informs us that the Marishal College library acquired its volume of Risner's *Opticae Thesaurus*... in 1613. The source is unknown, but correspond to the time when Alexander Anderson was active.

7. *Bonaventura Cavalieri, Marin Mersenne, and the Reflecting Telescope*. P. E. Ariotti. Isis 66 (1975), pp. 303-321.

§0.2 Gregory's Optics from a Modern Viewpoint.

The material presented here has been transcribed into modern language and published in The European Journal of Physics in Feb. 2006 with the title *'ABCD transfer matrices and paraxial ray tracing for elliptic and hyperbolic lenses and mirrors'* by the present writer. It can be viewed at stacks.org/EJP/27/393. Thus, we are in a good position to begin examining Gregory's work.

§0.3. The Method Used to Present the Material:

The work is divided into sections. A section of the work may be a single theorem, or a group of related theorems. These have been given a section number not present in the original, for reference purposes. The purest may not like this intrusion, but for most of us it is a useful addition. From my experiences with other translations, a satisfactory approach is one in which:
(i) a synopsis of a section of the work is first given in modern terminology;
(ii) a translation of the section is given in modern English. I try to avoid using ponderous Latin style sentences; the aim is to reproduce the meaning the original writer had in mind, which may or may not be a literal translation of the Latin text. Very occasionally there are sentences which I have found obscure, where I have had to take an educated guess at what Gregory meant. May I offer an apology for any of these which are incorrect. I have used simple present, past, and future tenses of verbs in line with modern math/physics text usage rather than subjunctives etc in a slavish manner.
(iii) notes and comments as referenced in (ii);
(iv) the original Latin text for the whole section is lumped together.

The translation is hence several approaches rolled into one. You are at liberty to read only the synoptic material in (i); or you can read sections (i) - (iii); while a Latin orientated person may wish to read the last section also.

In general, diagrams are labelled according to the Theorem or Problem they relate to. There are of course no such labels in the original text. These diagrams are set out in the translation section and not repeated in section (iv). Occasionally there is a need for extended explanatory diagrams in section (i), relating Gregory's diagrams to those we have already discussed above in §0. There is no table of contents in the original, which we have added rather fully to enable you to navigate the text, and there is no index. We commence with the title page, followed by the Preface and Definitions. A dedication to Charles II is not included. The original work is set out rather in the form of Euclid's Geometry. Gregory was a top-notch mathematician, and I have had to labour greatly to produce a mathematical scheme that agrees with his geometrical approach in this first section. Very occasionally he has made arithmetical errors that I have corrected. His knowledge of the physiological optics of the eye was of course rudimentary and often wrong.

OPTICA PROMOTA,

(*The Advancement of Optics*)
Seu
(*or*)
Abdita radiorum reflexorum & refractorum
(*The mysteries of the reflection and refraction of rays are resolved,*)

MYSTERIA,

Geometrice Enucleata ;
(*elucidated with the aid of geometry;*)
Cui subnectitur
(*to which is added an appendix*)

APPENDIX,

Subtilissimorum Astronomiae
Problematum resolutionem
exhibens.
(*demonstrating the resolution of the most subtle astronomical problems.*)

Authore *Jacobo Gregorio,*
Aberdonensi *Scoto.*

LONDINI.
Excudebat *F. Hayes*, pro *S. Thomas,* ad Insigne
Episcopi, in Coemeterio Paulino, 1663.

§0.4. To Mathematical Readers.

It is a superfluous task in your work on optics - that outstanding light of the learned! - to extol the wonders of optics For optics offers a number of aids to vision - the keenest of the senses. The use of special lenses affords the clearest possible vision for those people who are short or long-sighted, excepting eye defects caused by disease. The telescope enables us to look skywards to view the starry heavens - for most of us an unknown and incredible place. Again, the microscope enlarges the appearance of the smallest object for our careful examination. Thus optics supplies a useful handle to all the natural sciences, allowing things either to be made larger or to be brought nearer for distinct viewing.

Nevertheless when considered among all the mathematical sciences, nothing of any great consequence (as far as I know) has been handed down to us from antiquity [1] *: for with due regard for things from the olden times, and with the exclusion of the optics of Euclid, Alhazen* [or I*bn Al-Hasan, etc,* (965 - 1038)] *and Witelo* [*Vitellius* (1220 - 1280)][2]*, very few of the other obscure and long-winded authors appear to have offered much by way of improvement. But in recent times following Galileo*[3]*- a man for all time most worthy of our praise - many have striven at great cost to themselves to garner in their works some of the bountiful harvest of ideas left by that Mercurial star. I include myself among such people, urged on by a certain youthful ardour and boldness that arose from my readings of the discovery of the elliptic inequality* [*i.e. Kepler's Laws*] *. To this end, I have equipped myself with the necessary mathematical means to facilitate the optical speculations set out here, that terminate with the design of new telescopes of particular geometries*[4]*.*

From the analogies indicated in the first proposition of this small tract, I have revealed a hypothesis for the measurement of natural refractions. Clearly I was unaware - on account of the lack of new Mathematical books in the otherwise renowned Aberdeen University library - [Gregory's brother David was the librarian there] *that the same has already been found by Descartes. Following this I made use of a few Lemmas selected from the Commentary on Archimedes by Rivault*[5]*, to 26 of these I have added problems. Subsequently, I was in difficulties for a long space of time, deprived of all hope of progress* [*i.e.* in understanding image formation by lenses and mirrors]*; but with the continuing encouragement and help of my brother David Gregory, a man of no mean ability in mathematics - to whom I am truly indebted, if in whatever of these sciences I should excel. Finally I have produced a series of diagrams for consideration, and I have taken the image* [formed by a lens] *to be nothing more than the divergence of the rays from the individual visible points coming from a single surface* [of a source or previous image]*. I have added Corollaries to the individual problems considered to aid the examination of these images.*

I have added Theorems 26 and 27 concerning pencils and the determination of the cones of rays. Theorems 28, 29, 30, 31, 32, 34, 35, 36 account for the position of the image, and 33 for seeing a distinct image. Theorems 37, 38, 39, 40, 41, 42, 43 take care of the position of the apices of the pencils and cones of rays. Finally, from this presentation the most general propositions are readily shown by geometrical demonstration: all of reflection [by conoid mirrors]*, and the understanding of refraction* [by conoid surfaces]*, as with a denser transparent medium so with the less dense case*

considered together. From these theoretical considerations there finally emerge new kinds of optical instruments, some already known about, and some unknown - especially the telescope.

Finally I have added an Appendix on Astronomy; in which all that can be desired to be known about parallax, ellipses, and apparent diameters can be found from observation, with the help of the optical devices I have designed. As for a disgrace to the art of Astronomy, namely the parallax of the sun [*i.e.* a reliable estimate of the earth/sun distance]*, I demonstrate different ways of finding this* [by using the transits of Mercury and Venus]*. And finally, I show all the inequalities of the planets which I have examined closely many times. However, I have abandoned any attempt at explaining the moon's motion, on account of so much irregularity*.[This had originally been discovered by Galileo.] *For from these irregular motions which we may cast up in the course of our late night studies, I can say that I have struggled in vain with the foremost mathematics to generate an orbit. So one must relish even the attempt, but file it away in the drawer of our slavish trials!*

Yours most observantly,

J. G.

Notes & References for §0.7.

Gregory had apparently just finished reading Descartes' First discussion in the *Dioptique* when he amended his manuscript, as there is a faint echo of that philosopher's line of thought in the opening paragraph of the *O.P.*

1. Gregory fails to mention Ptolemy's *Optics*, which is a treasure house of classical optics. See *Ptolémé. L'Optique de Claude Ptolémé.*. Albert Lejeune. Louvin University.(1956). Also, A.M. Smith : *Ptolemy's Theory of visual perception*. *An English translation of the Optics*... Transactions of the American Philosophical Society 86, Pt 2. (1996).

2. *Opticae Thesaurus Alhazeni Arabis.....item Vitellonis*....Federico Risnero. Basile (1572). Available in libraries, from the Johnson Reprint Corporation (1972).

3. *Siderius Nuncius.* Galileo. (1610).

4. Such as in Kepler's *Optics*, translated by W. Donahue, Green Lion Press, 2000.

5. *Archimedes*: *Opera quae exstant graece et latine novis demon*....; Rivault.(Paris, 1615).

§0.5. Definitions.

1. *Rays are the lines along which the fiery corpuscles run that arise from light producing bodies.*
2. *A body shining* [from diffuse reflected light] *is opaque and unpolished, reflecting some of the fiery corpuscles, and absorbing others.*
3. *The colour conveyed into the eye is the tincture of the fiery corpuscles emerging from the radiating material.*
4. *Vision shall be from the reception of these corpuscles reflected from a shining body, and conveying the colour into the eye.*
5. *The rays of a single point are those which have been reflected from one point of a shining body.*

6. *Parallel rays are those which are always equally distant each to the other amongst themselves.*
7. *Diverging rays are those which concur in a point when produced in both directions: those rays produced in the opposite direction to the motion form the ray-bearing cone - the apex of the cone is the point of concurrence of the rays.*
8. *Converging rays are those which concur in a point in the direction of the motion when produced in both directions; these rays are called a pencil, and the point of concurrence the apex of the pencil.*
   It is to be noted however, that the terms parallelism, divergence, and convergence are to be applied only to rays coming from a single point.
9. *The image produced by a lens or mirror is a likeness of the radiating body, arising either from the divergence or convergence of rays from single points of the shining body, to or from the individual points of the one image surface.*
10. *An image before the eye* [*i.e.* a real image]*, arises from the apices of the light bearing cones from single radiating points of matter, brought together in a single surface.*
11. *The image behind the eye* [*i.e.* a virtual image] *arises from the apices of the pencils of single radiating points of matter, brought together in a single structure [behind the lens or mirror]; although it is not properly said to be an image, nevertheless in optics it is scarcely less effective than the [real] image before the eye.*
12. *An object visible to the eye is produced either by a luminous body, or from a previous real or virtual image* [produced by a lens or mirror]*; nevertheless more often the term is used for a radiating body, especially so when the talk is about the image.*
13. *The diameter of a visible object is the distance between any two extreme and opposite points.*
14. *The centre of visibility is the mid-point of the diameter.*
15. *The angle of vision is the angle taken by the two rays from the extreme visible points, intersecting in the centre of the surface of the eye.*
16. *The sections of conics are the circle, ellipse, parabola, hyperbola, and straight lines.*
17. *The line of the conic section, or the circumference, is the common section of the plane cutting the surface of the cone.*
18. *A right line is said to be perpendicular to the circumference of a conic section when it cuts the tangent at the point of contact at right angles.*
19. *Conical surfaces are the surfaces of figures generated by the revolution of sections of the cone about individual axes.*
20. *A mirror is an opaque polished body fashioned from one conical surface.*
21. *A lens is a transparent polished body fashioned from two conical surfaces with a common axis.*
22. *The axis of a lens or mirror is the same as the axis of the conical surfaces from which it is comprised.*
23. *The vertices of mirrors or lenses are the same as the vertices of the conical surfaces from which the mirror or lens is comprised.*
24. *The incident vertex is that in which the rays are incident, the vertex of the emergent rays is that from which they emerge; from which it appears that these vertices coincide for mirrors, while with lenses they are truly separated.*
25. *The thickness of the lens is the difference in length of the vertices.*

26. The diameter of the lens or mirror is the distance between two of their extreme and opposite points; and hence the centre of the lens or mirror is the mid point of the diameter.
27. The angle containing the rays is the angle taken from the centre of the visible and the diameter of the lens or the mirror.
28. The axis of the pencil, or of the ray bearing cone, is that ray which is at right angles to the surface of the mirror or lens.
29. The nearest image is that which is seen immediately by the eye; the second image that by means of which the first image is seen by the eye; and thus in succession [*for a sequence of lenses or lenses with a mirror*]*: But the furthest image is the first image projected, and therefore brought to the eye by all the remaining intermediate images.*
30. The rays of the first, second, third, and the final image, etc., are those which converge to the first, second image, etc. ; or which diverge from the same.
31. The incident vertex of the first image, of the second, third, etc., is the vertex of incidence of that lens or mirror in which the rays are incident, of the first image, of the second, etc.; and in the same way the vertex of these emergent is the vertex of the emergent lens, or mirror, from which these emerge.
32. The telescope is an optical device with lenses or mirrors placed together, having a common axis, allowing the accurate vision of things far away.
33. The microscope is an optical device with lenses or mirrors placed together, having a common axis, allowing the accurate vision of things nearby.
34. The icoscope is an optical device with lenses or mirrors, having a common axis, depicting visible images in a plane [*i.e. a projecting telescope or microscope*]*.*
35. Relating to the first, second, third, etc., image, is the mirror or lens, projecting the first, second, third, etc., image.
36. Long - sighted [*usually elderly*] *people are those who see far away objects distinctly, while nearby things are indistinct.*
37. *Myopic* [*i.e. short - sighted*] *are those who see far away things indistinctly, nearby things distinctly.*

§0.6. **Postulates**.

1. Light rays are weakened by their distance from the source;
2. Rays cannot be weakened by reflection alone from mirrors ; otherwise corpuscles would be destroyed, which cannot happen;
3. Rays transmitted are weakened by refraction, because a great fraction of the corpuscles are reflected backwards at the common interface of different transparencies.
4. The rays coming from remote visible objects are considered to be parallel.
5. From a given axis and foci of a conic section, the section itself is given.

§0.7. *Lectoribus Mathematicis.*

Supervacaneum esset (praeclara Literarum lumina) de mirandis Optices Encomiis apud vos panegyricum instituere; visum enim sensuum pulcherrimum adjuvat; myopibus & presbytis (absque; Optices ope quodammodo caecis) clarissimum praebet visum; oculos humanos ab hisce terrestribus, ad caelestia majoribus nostris incognita, & incredibilia elevat; & ad perfectam minutissimorum corporum

visionem rursus detrudit: Unde ansam praebet, omnes scientiae naturales, & amplificandi, & promovendi. Nihilominus inter universas scientias Mathematicas, nulla ab antiquis adeo neglecta, & a paucioribus exculta: Omissis enim Euclide, Alhazeno, & Vitellione, authoribus etiam perobscuris & prolixis; e veteribus nullus aliquid momenti (quantum scio) nobis reliquit: E neotericis autem, post Galilaeum sidereum illum Mercurium, & omni aevo laudibus celebrandum, multi, & scriptis, & sumptibus immensis, in hac messe laudabiliter sudarunt: inter quos ego, juvenili quodam ardore instigatus, & ex inventione inaequalitatis ellipticae audaciam nactus, hisce speculationibus Opticis, & praecipuae geometricae Telescopiorum demonstrationi, pro facultate ingenii me accinxi; & ex analogiis in prima huius tractatuli propositione declaratis, inveni primam hujus Opticae partem, de genuina refractionum hypothesi & mensura; nescius scilicet (propter inopiam novorum librorum Mathematicorum, in alias inclytae Bibliothecae Aberdoneinsi) haec eadem a Cartesio fuisse inventa: & ope aliquot Lemmatum, e Rivalti Commentariis in Archemedem desumptorum, Problemata ad 26 huius adjunxi: ubi diu haesi omni spe progrediendi orbatus; sed continuis hortatibus, & auxiliis fratris mei Davidis Gregorii in Mathematicis non parum versati (cui, si quid in hisce scientiis praestitero, me illud debere non inficias ibo) animatus, tandem incidi in seriam imaginis considerationem, & deprehendi imaginem nihil aliud esse, quam radiorum, singulorum visibilis punctorum, a singulis aliis punctis in una superficie existentibus, divergentiam: quo perspecto, singulis problematibus addidi sua Corollaria; & adjunxi 26, 27, pencillorum, & conorum radiorum determinationi; 28, 29, 30, 31, 32, 34, 35, 36, imaginis loco, & visioni distinctae, 33 ; 37, 38, 39, 40, 41, 42, 43, apicum, penicillorum & conorum radio[so]rum, loco inservientes. Quibus praemissis, usque; ad finem patent facillima & universalissimae propositiones geometricae demonstratae, totam Catoptricorum, & Dioptricorum doctrinam, tam mediante diaphano densiore, quam rariore comprehendentes: e quibus emergunt infinita machinamenta Optica diversa, partim ante cognita, partim incognita. Deinde appendicem astronomicam addo; in qua, omnia desiderata de parallaxium, eclipsium, & diametrorum apparentiuim observationibus, ope machinarum opticarum perficio: & Astronomorum opprobrium, nempe solis parallaxim diversis modis invenire doceo: Et denique; omnes planetarum inaequalitates scrutari multipliciter demonstro; Lunam tantum propter maxime irregularem motum vix tactam relinquens. His inquam molitus sum praeclara Mathematica propagare: quod si in nostris lucubrationibus humanius quid acciderit, conatum saltem fovete; & servorum vestrorum catalogo inserite.

Vestri Observantissimum,

J. G.

[1]

Definitiones.

1. Radii sunt linea, in quibus discurrunt corpuscula ignea, è corporibus lucidis ortum habentia.

2. Materia radians, est corpus opacum, & impolitum, corpuscula ignea reflectens, & aliquem illis praebens ingressum.

3. Color in oculum delatus, est tinctura corpusculorum igneorum, è materiâ radiante emergentium.

4. Visio sit receptione horum corpusculorum a materia radiante reflexorum, & colorem in oculum deferentium.

5. Radii unius puncti, sunt qui ab uno materiae radiantis puncto reflectuntur.

6. Radii paralleli, sunt qui aequaliter semper a se invicem distant.

7. Radii divergentes, sunt qui utrinque producti concurrunt in punctum, ad partes motus contrarias; & vocantur hi radii conus radiorum & punctum concursus apex coni.

8. Radii convergentes, sunt qui utrinque producti concurrunt ad partes motus, & vocantur penicillum, & punctum concursus apex penicilli.

Notandum tamen, parallelismum, divergentiam, & convergentiam, applicari tantum unius puncti radiis.

9. Imago est similitudo materiae radiantis, orsa ex divergentiâ, vel convergentiâ radiorum, singulorum materiae radiantis punctorum, a punctis singulis, vel ad puncta singula unius superficiei.

10. Imago ante oculum, oritur ex apicibus conorum radiosorum, singulorum materiae radiantis punctorum, in una superficie congregatis.

11. Imago post oculum, oritur ex apicibus pencillorum, singulorum materiae radiantis punctorum,

[2]

in una superficie congregatis; qua non propriè dicitur imago, sed tamen in Opticis, vix minorem habet efficaciam , quàm imago ante oculum.

12. Visibile est, sive materie radians, sive imago ante, sive post oculam; saepius tamen usurpatur, pro materiâ radiante, praesertim ubi sermo etiam est de imagine.

13. Diameter visibilis, est distantia inter qualibet duo puncta extrema, & opposita.

14. Centrum visibilis, est diametri punctum medium.

15. Angulus visorius,, est anguli comprehensus a duobus radiis, extremorum visibilis punctorum, in centro oculi, se invicem secantibus.

16. Sectiones Conica sunt, circulus, ellipsis, parabola, hyperbola, linea recta.

17. Sectiones conicae linea, seu circumferentia, est communis sectio plani secantis cum superficie coni.

18. Linea recta dicitur esse circumferentiae sectionis conicae perpendicularis; cum secat contingentem in puncto contactus ad angulos rectos.

19. Superficies conicae, sunt superficies figurarum, ex revolutione sectorum conicarum circa proprios axes, genitarum.

20. Speculum est corpus opacum, & politum, ab una superficie conica à comprehensum.

21. Lens est corpus diaphanum, & politum, a duobus superficiebus conicis, communem axem habentibus, comprehensum.

22. Axis lentis, vel speculum. est idem cum axe superficierum conicarum, a quibus comprehenditur.

23. Vertices lentis, vel speculi, sunt eadem cum verticibus superficierum conicarum, a quibus comprehenditur lens vel speculum.

24. Vertex incidentiae, est illa, in quam incidunt radii: vertex emersionis, illa, ex qua emergunt: Unde patet, in speculis hae vertices esse unam; in lentibus vero diversas.

25. Crassities lentis, est verticum distantia.

26. Diameter lentis, vel speculi, est distantia inter duo ipsius puncta extrema & opposita; & proinde centrum lentis, vel speculi, est diametri punctum medium.

27. Angulus radiosus, est angulus comprehensus a centro visibilis, & diametro lentis, vel speculi.

[3]

28. Axis penicilli, vel coni radiosi, est ille radius, qui ad superficiem speculi, vel lentis, est rectus.

29. Imago prima, est illa, quae immediatè ab oculo videtur; imago secundo, illa quae mediante imagino prima ab oculo videtur; & sic deinceps: Imago autem ultima, est imago visibilis primò projecta, & ideo mediantibus omnibus reliquis, in oculum allata.

30. Radii imaginis primis, secundae, tertae, ultimae, &c., sunt illi, qui ad imaginem primam, secundam, &c., convergunt, vel ab iisdem divergunt.

31. Vertex incidentiae, imaginis primae, secundae, tertiae, &c., est vertex incidentiae, illius lentis, vel speculi, in quam incidunt radii, imaginis primae, secundae, &c.; & eodem modo vertex earum emersionis, est vertex emersionis lentis, vel speculi, ex quà emergunt earum radii.

32. Telescopium, est machina optica, ex lentibus, vel speculi, communem axem habentibus, composita ; longinquorum efficiens accuratem visionem.

33. Microscopium, est machina optica, ex lentibus, vel speculis, communem axem habentibus, composita; propinquorum efficiens accuratam visionem.

34. Icoscopium, est machina optica, ex lentibus, vel speculis, composita; visibilium imagines in plano depingens.

35. Pertinens ad imaginem primam, secundam, tertiam, &c., est speculum, vel lens, projiciens imaginem primam, secundem, tertiam, &c.

36. Presbyti sunt, qui remota distinctè videns; propinqua confuse.

37. Myopes sunt, qui remota confusè vident ; propinqua distinctè.

Postulata.

1. Radii non debilitantur, solâ distantià a radiante.

2. Radii non debilitantur, solâ reflectione a speculis ; alioquin corpus annihilaretur, quod fieri non potest.

3. Radii debilitantur, sola refractione, quoniam eorum plerique in superficie diversorum diaphanorum communi, ad contrarias partes reflectuntur.

4. Radii visibilium longinquorum, sunt quo ad sensum paralleli.

5. E datis, axi, & focis sectionis conicae, datur & ipsa sectio.