EUCLID'S ELEMENTS OF GEOMETRY

The Greek text of J.L. Heiberg (1883–1885)

from *Euclidis Elementa, edidit et Latine interpretatus est I.L. Heiberg, in aedibus B.G. Teubneri, 1883–1885*

edited, and provided with a modern English translation, by

Richard Fitzpatrick

Introduction

Euclid's Elements is by far the most famous mathematical work of classical antiquity, and also has the distinction of being the world's oldest continuously used mathematical textbook. Little is known about the author, beyond the fact that he lived in Alexandria around 300 BCE. The main subjects of the work are geometry, proportion, and number theory.

Most of the theorems appearing in the Elements were not discovered by Euclid himself, but were the work of earlier Greek mathematicians such as Pythagoras (and his school), Hippocrates of Chios, Theaetetus of Athens, and Eudoxus of Cnidos. However, Euclid is generally credited with arranging these theorems in a logical manner, so as to demonstrate (admittedly, not always with the rigour demanded by modern mathematics) that they necessarily follow from five simple axioms. Euclid is also credited with devising a number of particularly ingenious proofs of previously discovered theorems: *e.g.*, Theorem 48 in Book 1.

The geometrical constructions employed in the Elements are restricted to those which can be achieved using a straight-rule and a compass. Furthermore, empirical proofs by means of measurement are strictly forbidden: *i.e.*, any comparison of two magnitudes is restricted to saying that the magnitudes are either equal, or that one is greater than the other.

The Elements consists of thirteen books. Book 1 outlines the fundamental propositions of plane geometry, including the three cases in which triangles are congruent, various theorems involving parallel lines, the theorem regarding the sum of the angles in a triangle, and the Pythagorean theorem. Book 2 is commonly said to deal with "geometric algebra", since most of the theorems contained within it have simple algebraic interpretations. Book 3 investigates circles and their properties, and includes theorems on tangents and inscribed angles. Book 4 is concerned with regular polygons inscribed in, and circumscribed around, circles. Book 5 develops the arithmetic theory of proportion. Book 6 applies the theory of proportion to plane geometry, and contains theorems on similar figures. Book 7 deals with elementary number theory: *e.g.*, prime numbers, greatest common denominators, *etc.* Book 8 is concerned with geometric series. Book 9 contains various applications of results in the previous two books, and includes theorems on the infinitude of prime numbers, as well as the sum of a geometric series. Book 10 attempts to classify incommensurable (*i.e.*, irrational) magnitudes using the so-called "method of exhaustion", an ancient precursor to integration. Book 11 deals with the fundamental propositions of three-dimensional geometry. Book 12 calculates the relative volumes of cones, pyramids, cylinders, and spheres using the method of exhaustion. Finally, Book 13 investigates the five so-called Platonic solids.

This edition of Euclid's Elements presents the definitive Greek text—*i.e.*, that edited by J.L. Heiberg (1883–1885)—accompanied by a modern English translation, as well as a Greek-English lexicon. Neither the spurious books 14 and 15, nor the extensive scholia which have been added to the Elements over the centuries, are included. The aim of the translation is to make the mathematical argument as clear and unambiguous as possible, whilst still adhering closely to the meaning of the original Greek. Text within square parenthesis (in both Greek and English) indicates material identified by Heiberg as being later interpolations to the original text (some particularly obvious or unhelpful interpolations have been omitted altogether). Text within round parenthesis (in English) indicates material which is implied, but not actually present, in the Greek text.

ELEMENTS BOOK 1

Fundamentals of plane geometry involving straight-lines

Ὅροι.

α΄. Σημεῖόν ἐστιν, οὗ μέρος οὐθέν.

β΄. Γραμμὴ δὲ μῆκος ἀπλατές.

γ΄. Γραμμῆς δὲ πέρατα σημεῖα.

δ΄. Εὐθεῖα γραμμή ἐστιν, ἥτις ἐξ ἴσου τοῖς ἐφ᾿ ἑαυτῆς σημείοις κεῖται.

ε΄. Ἐπιφάνεια δέ ἐστιν, ὃ μῆκος καὶ πλάτος μόνον ἔχει.

ϛ΄. Ἐπιφανείας δὲ πέρατα γραμμαί.

ζ΄. Ἐπίπεδος ἐπιφάνειά ἐστιν, ἥτις ἐξ ἴσου ταῖς ἐφ᾿ ἑαυτῆς εὐθείαις κεῖται.

η΄. Ἐπίπεδος δὲ γωνία ἐστὶν ἡ ἐν ἐπιπέδῳ δύο γραμμῶν ἁπτομένων ἀλλήλων καὶ μὴ ἐπ᾿ εὐθείας κειμένων πρὸς ἀλλήλας τῶν γραμμῶν κλίσις.

θ΄. Ὅταν δὲ αἱ περιέχουσαι τὴν γωνίαν γραμμαὶ εὐθεῖαι ὦσιν, εὐθύγραμμος καλεῖται ἡ γωνία.

ι΄. Ὅταν δὲ εὐθεῖα ἐπ᾿ εὐθεῖαν σταθεῖσα τὰς ἐφεξῆς γωνίας ἴσας ἀλλήλαις ποιῇ, ὀρθὴ ἑκατέρα τῶν ἴσων γωνιῶν ἐστι, καὶ ἡ ἐφεστηκυῖα εὐθεῖα κάθετος καλεῖται, ἐφ᾿ ἣν ἐφέστηκεν.

ια΄. Ἀμβλεῖα γωνία ἐστὶν ἡ μείζων ὀρθῆς.

ιβ΄. Ὀξεῖα δὲ ἡ ἐλάσσων ὀρθῆς.

ιγ΄. Ὅρος ἐστίν, ὅ τινός ἐστι πέρας.

ιδ΄. Σχῆμά ἐστι τὸ ὑπό τινος ἤ τινων ὅρων περιεχόμενον.

ιε΄. Κύκλος ἐστὶ σχῆμα ἐπίπεδον ὑπὸ μιᾶς γραμμῆς περιεχόμενον [ἣ καλεῖται περιφέρεια], πρὸς ἣν ἀφ᾿ ἑνὸς σημείου τῶν ἐντὸς τοῦ σχήματος κειμένων πᾶσαι αἱ προσπίπτουσαι εὐθεῖαι [πρὸς τὴν τοῦ κύκλου περιφέρειαν] ἴσαι ἀλλήλαις εἰσίν.

ιϛ΄. Κέντρον δὲ τοῦ κύκλου τὸ σημεῖον καλεῖται.

ιζ΄. Διάμετρος δὲ τοῦ κύκλου ἐστὶν εὐθεῖά τις διὰ τοῦ κέντρου ἠγμένη καὶ περατουμένη ἐφ᾿ ἑκάτερα τὰ μέρη ὑπὸ τῆς τοῦ κύκλου περιφερείας, ἥτις καὶ δίχα τέμνει τὸν κύκλον.

ιη΄. Ἡμικύκλιον δέ ἐστι τὸ περιεχόμενον σχῆμα ὑπό τε τῆς διαμέτρου καὶ τῆς ἀπολαμβανομένης ὑπ᾿ αὐτῆς περιφερείας. κέντρον δὲ τοῦ ἡμικυκλίου τὸ αὐτό, ὃ καὶ τοῦ κύκλου ἐστίν.

ιθ΄. Σχήματα εὐθύγραμμά ἐστι τὰ ὑπὸ εὐθειῶν περιεχόμενα, τρίπλευρα μὲν τὰ ὑπὸ τριῶν, τετράπλευρα δὲ τὰ ὑπὸ τεσσάρων, πολύπλευρα δὲ τὰ ὑπὸ πλειόνων ἢ τεσσάρων εὐθειῶν περιεχόμενα.

κ΄. Τῶν δὲ τριπλεύρων σχημάτων ἰσόπλευρον μὲν τρίγωνόν ἐστι τὸ τὰς τρεῖς ἴσας ἔχον πλευράς, ἰσοσκελὲς δὲ τὸ τὰς δύο μόνας ἴσας ἔχον πλευράς, σκαληνὸν δὲ τὸ τὰς τρεῖς ἀνίσους ἔχον πλευράς.

κα΄ Ἔτι δὲ τῶν τριπλεύρων σχημάτων ὀρθογώνιον μὲν τρίγωνόν ἐστι τὸ ἔχον ὀρθὴν γωνίαν, ἀμβλυγώνιον

Definitions

1. A point is that of which there is no part.
2. And a line is a length without breadth.
3. And the extremities of a line are points.
4. A straight-line is whatever lies evenly with points upon itself.
5. And a surface is that which has length and breadth alone.
6. And the extremities of a surface are lines.
7. A plane surface is whatever lies evenly with straight-lines upon itself.
8. And a plane angle is the inclination of the lines, when two lines in a plane meet one another, and are not laid down straight-on with respect to one another.
9. And when the lines containing the angle are straight then the angle is called rectilinear.
10. And when a straight-line stood upon (another) straight-line makes adjacent angles (which are) equal to one another, each of the equal angles is a right-angle, and the former straight-line is called perpendicular to that upon which it stands.
11. An obtuse angle is greater than a right-angle.
12. And an acute angle is less than a right-angle.
13. A boundary is that which is the extremity of something.
14. A figure is that which is contained by some boundary or boundaries.
15. A circle is a plane figure contained by a single line [which is called a circumference], (such that) all of the straight-lines radiating towards [the circumference] from a single point lying inside the figure are equal to one another.
16. And the point is called the center of the circle.
17. And a diameter of the circle is any straight-line, being drawn through the center, which is brought to an end in each direction by the circumference of the circle. And any such (straight-line) cuts the circle in half.†
18. And a semi-circle is the figure contained by the diameter and the circumference it cuts off. And the center of the semi-circle is the same (point) as (the center of) the circle.
19. Rectilinear figures are those figures contained by straight-lines: trilateral figures being contained by three straight-lines, quadrilateral by four, and multilateral by more than four.
20. And of the trilateral figures: an equilateral triangle is that having three equal sides, an isosceles (triangle) that having only two equal sides, and a scalene (triangle) that having three unequal sides.

δὲ τὸ ἔχον ἀμβλεῖαν γωνίαν, ὀξυγώνιον δὲ τὸ τὰς τρεῖς ὀξείας ἔχον γωνίας.

κβ′. Τῶν δὲ τετραπλεύρων σχημάτων τετράγωνον μέν ἐστιν, ὃ ἰσόπλευρόν τέ ἐστι καὶ ὀρθογώνιον, ἑτερόμηκες δέ, ὃ ὀρθογώνιον μέν, οὐκ ἰσόπλευρον δέ, ῥόμβος δέ, ὃ ἰσόπλευρον μέν, οὐκ ὀρθογώνιον δέ, ῥομβοειδὲς δὲ τὸ τὰς ἀπεναντίον πλευράς τε καὶ γωνίας ἴσας ἀλλήλαις ἔχον, ὃ οὔτε ἰσόπλευρόν ἐστιν οὔτε ὀρθογώνιον· τὰ δὲ παρὰ ταῦτα τετράπλευρα τραπέζια καλείσθω.

κγ′. Παράλληλοί εἰσιν εὐθεῖαι, αἵτινες ἐν τῷ αὐτῷ ἐπιπέδῳ οὖσαι καὶ ἐκβαλλόμεναι εἰς ἄπειρον ἐφ᾽ ἑκάτερα τὰ μέρη ἐπὶ μηδέτερα συμπίπτουσιν ἀλλήλαις.

21. And further of the trilateral figures: a right-angled triangle is that having a right-angle, an obtuse-angled (triangle) that having an obtuse angle, and an acute-angled (triangle) that having three acute angles.

22. And of the quadrilateral figures: a square is that which is right-angled and equilateral, a rectangle that which is right-angled but not equilateral, a rhombus that which is equilateral but not right-angled, and a rhomboid that having opposite sides and angles equal to one another which is neither right-angled nor equilateral. And let quadrilateral figures besides these be called trapezia.

23. Parallel lines are straight-lines which, being in the same plane, and being produced to infinity in each direction, meet with one another in neither (of these directions).

† This should really be counted as a postulate, rather than as part of a definition.

Αἰτήματα.

α′. Ἠιτήσθω ἀπὸ παντὸς σημείου ἐπὶ πᾶν σημεῖον εὐθεῖαν γραμμὴν ἀγαγεῖν.

β′. Καὶ πεπερασμένην εὐθεῖαν κατὰ τὸ συνεχὲς ἐπ᾽ εὐθείας ἐκβαλεῖν.

γ′. Καὶ παντὶ κέντρῳ καὶ διαστήματι κύκλον γράφεσθαι.

δ′. Καὶ πάσας τὰς ὀρθὰς γωνίας ἴσας ἀλλήλαις εἶναι.

ε′. Καὶ ἐὰν εἰς δύο εὐθείας εὐθεῖα ἐμπίπτουσα τὰς ἐντὸς καὶ ἐπὶ τὰ αὐτὰ μέρη γωνίας δύο ὀρθῶν ἐλάσσονας ποιῇ, ἐκβαλλομένας τὰς δύο εὐθείας ἐπ᾽ ἄπειρον συμπίπτειν, ἐφ᾽ ἃ μέρη εἰσὶν αἱ τῶν δύο ὀρθῶν ἐλάσσονες.

Postulates

1. Let it have been postulated to draw a straight-line from any point to any point.

2. And to produce a finite straight-line continuously in a straight-line.

3. And to draw a circle with any center and radius.

4. And that all right-angles are equal to one another.

5. And that if a straight-line falling across two (other) straight-lines makes internal angles on the same side (of itself whose sum is) less than two right-angles, then, being produced to infinity, the two (other) straight-lines meet on that side (of the original straight-line) that the (sum of the internal angles) is less than two right-angles (and do not meet on the other side).†

† This postulate effectively specifies that we are dealing with the geometry of *flat*, rather than curved, space.

Κοιναὶ ἔννοιαι.

α′. Τὰ τῷ αὐτῷ ἴσα καὶ ἀλλήλοις ἐστὶν ἴσα.

β′. Καὶ ἐὰν ἴσοις ἴσα προστεθῇ, τὰ ὅλα ἐστὶν ἴσα.

γ′. Καὶ ἐὰν ἀπὸ ἴσων ἶσα ἀφαιρεθῇ, τὰ καταλειπόμενά ἐστιν ἴσα.

δ′. Καὶ τὰ ἐφαρμόζοντα ἐπ᾽ ἀλλήλα ἴσα ἀλλήλοις ἐστίν.

ε′. Καὶ τὸ ὅλον τοῦ μέρους μεῖζόν [ἐστιν].

Common Notions

1. Things equal to the same thing are also equal to one another.

2. And if equal things are added to equal things then the wholes are equal.

3. And if equal things are subtracted from equal things then the remainders are equal.†

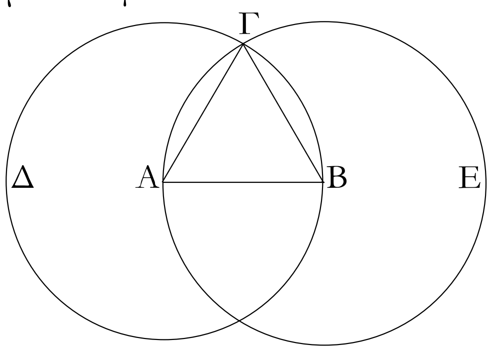
4. And things coinciding with one another are equal to one another.

5. And the whole [is] greater than the part.

† As an obvious extension of C.N.s 2 & 3—if equal things are added or subtracted from the two sides of an inequality then the inequality remains an inequality of the same type.

α΄.

Ἐπὶ τῆς δοθείσης εὐθείας πεπερασμένης τρίγωνον ἰσόπλευρον συστήσασθαι.



Ἔστω ἡ δοθεῖσα εὐθεῖα πεπερασμένη ἡ ΑΒ.

Δεῖ δὴ ἐπὶ τῆς ΑΒ εὐθείας τρίγωνον ἰσόπλευρον συστήσασθαι.

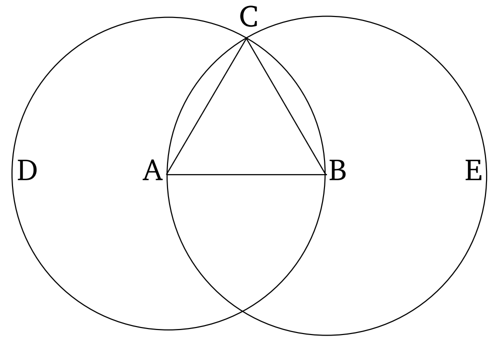
Κέντρῳ μὲν τῷ Α διαστήματι δὲ τῷ ΑΒ κύκλος γεγράφθω ὁ ΒΓΔ, καὶ πάλιν κέντρῳ μὲν τῷ Β διαστήματι δὲ τῷ ΒΑ κύκλος γεγράφθω ὁ ΑΓΕ, καὶ ἀπὸ τοῦ Γ σημείου, καθ᾽ ὃ τέμνουσιν ἀλλήλους οἱ κύκλοι, ἐπί τὰ Α, Β σημεῖα ἐπεζεύχθωσαν εὐθεῖαι αἱ ΓΑ, ΓΒ.

Καὶ ἐπεὶ τὸ Α σημεῖον κέντρον ἐστὶ τοῦ ΓΔΒ κύκλου, ἴση ἐστὶν ἡ ΑΓ τῇ ΑΒ· πάλιν, ἐπεὶ τὸ Β σημεῖον κέντρον ἐστὶ τοῦ ΓΑΕ κύκλου, ἴση ἐστὶν ἡ ΒΓ τῇ ΒΑ. ἐδείχθη δὲ καὶ ἡ ΓΑ τῇ ΑΒ ἴση· ἑκατέρα ἄρα τῶν ΓΑ, ΓΒ τῇ ΑΒ ἐστιν ἴση. τὰ δὲ τῷ αὐτῷ ἴσα καὶ ἀλλήλοις ἐστὶν ἴσα· καὶ ἡ ΓΑ ἄρα τῇ ΓΒ ἐστιν ἴση· αἱ τρεῖς ἄρα αἱ ΓΑ, ΑΒ, ΒΓ ἴσαι ἀλλήλαις εἰσίν.

Ἰσόπλευρον ἄρα ἐστὶ τὸ ΑΒΓ τρίγωνον. καὶ συνέσταται ἐπὶ τῆς δοθείσης εὐθείας πεπερασμένης τῆς ΑΒ· ὅπερ ἔδει ποιῆσαι.

Proposition 1

To construct an equilateral triangle on a given finite straight-line.



Let AB be the given finite straight-line.

So it is required to construct an equilateral triangle on the straight-line AB.

Let the circle BCD with center A and radius AB have been drawn [Post. 3], and again let the circle ACE with center B and radius BA have been drawn [Post. 3]. And let the straight-lines CA and CB have been joined from the point C, where the circles cut one another,† to the points A and B (respectively) [Post. 1].

And since the point A is the center of the circle CDB, AC is equal to AB [Def. 1.15]. Again, since the point B is the center of the circle CAE, BC is equal to BA [Def. 1.15]. But CA was also shown (to be) equal to AB. Thus, CA and CB are each equal to AB. But things equal to the same thing are also equal to one another [C.N. 1]. Thus, CA is also equal to CB. Thus, the three (straight-lines) CA, AB, and BC are equal to one another.

Thus, the triangle ABC is equilateral, and has been constructed on the given finite straight-line AB. (Which is) the very thing it was required to do.

† The assumption that the circles do indeed cut one another should be counted as an additional postulate. There is also an implicit assumption that two straight-lines cannot share a common segment.

β΄.

Πρὸς τῷ δοθέντι σημείῳ τῇ δοθείσῃ εὐθείᾳ ἴσην εὐθεῖαν θέσθαι.

Ἔστω τὸ μὲν δοθὲν σημεῖον τὸ Α, ἡ δὲ δοθεῖσα εὐθεῖα ἡ ΒΓ· δεῖ δὴ πρὸς τῷ Α σημείῳ τῇ δοθείσῃ εὐθείᾳ τῇ ΒΓ ἴσην εὐθεῖαν θέσθαι.

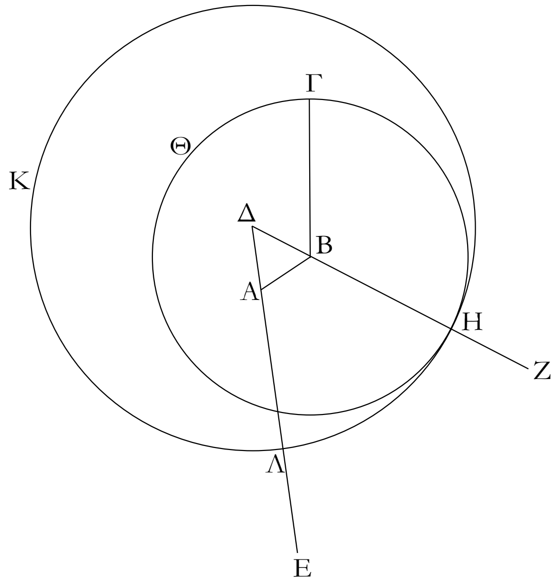
Ἐπεζεύχθω γὰρ ἀπὸ τοῦ Α σημείου ἐπί τὸ Β σημεῖον εὐθεῖα ἡ ΑΒ, καὶ συνεστάτω ἐπ᾽ αὐτῆς τρίγωνον ἰσόπλευρον τὸ ΔΑΒ, καὶ ἐκβεβλήσθωσαν ἐπ᾽ εὐθείας ταῖς ΔΑ, ΔΒ εὐθεῖαι αἱ ΑΕ, ΒΖ, καὶ κέντρῳ μὲν τῷ Β διαστήματι δὲ τῷ ΒΓ κύκλος γεγράφθω ὁ ΓΗΘ, καὶ πάλιν κέντρῳ τῷ Δ καὶ διαστήματι τῷ ΔΗ κύκλος

Proposition 2†

To place a straight-line equal to a given straight-line at a given point.

Let A be the given point, and BC the given straight-line. So it is required to place a straight-line at point A equal to the given straight-line BC.

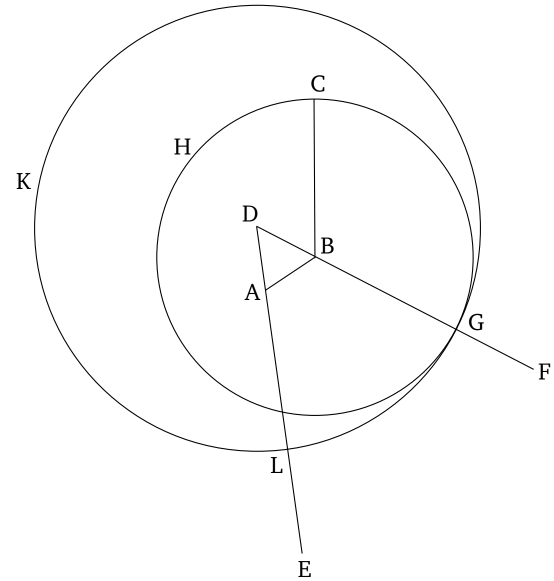
For let the straight-line AB have been joined from point A to point B [Post. 1], and let the equilateral triangle DAB have been been constructed upon it [Prop. 1.1]. And let the straight-lines AE and BF have been produced in a straight-line with DA and DB (respectively) [Post. 2]. And let the circle CGH with center B and raγεγράφθω ὁ ΗΚΛ.



Ἐπεὶ οὖν τὸ Β σημεῖον κέντρον ἐστὶ τοῦ ΓΗΘ, ἴση ἐστὶν ἡ ΒΓ τῇ ΒΗ. πάλιν, ἐπεὶ τὸ Δ σημεῖον κέντρον ἐστὶ τοῦ ΗΚΛ κύκλου, ἴση ἐστὶν ἡ ΔΛ τῇ ΔΗ, ὧν ἡ ΔΑ τῇ ΔΒ ἴση ἐστίν. λοιπὴ ἄρα ἡ ΑΛ λοιπῇ τῇ ΒΗ ἐστιν ἴση. ἐδείχθη δὲ καὶ ἡ ΒΓ τῇ ΒΗ ἴση· ἑκατέρα ἄρα τῶν ΑΛ, ΒΓ τῇ ΒΗ ἐστιν ἴση. τὰ δὲ τῷ αὐτῷ ἴσα καὶ ἀλλήλοις ἐστὶν ἴσα· καὶ ἡ ΑΛ ἄρα τῇ ΒΓ ἐστιν ἴση.

Πρὸς ἄρα τῷ δοθέντι σημείῳ τῷ Α τῇ δοθείσῃ εὐθείᾳ τῇ ΒΓ ἴση εὐθεῖα κεῖται ἡ ΑΛ· ὅπερ ἔδει ποιῆσαι.

dius BC have been drawn [Post. 3], and again let the circle GKL with center D and radius DG have been drawn [Post. 3].



Therefore, since the point B is the center of (the circle) CGH, BC is equal to BG [Def. 1.15]. Again, since the point D is the center of the circle GKL, DL is equal to DG [Def. 1.15]. And within these, DA is equal to DB. Thus, the remainder AL is equal to the remainder BG [C.N. 3]. But BC was also shown (to be) equal to BG. Thus, AL and BC are each equal to BG. But things equal to the same thing are also equal to one another [C.N. 1]. Thus, AL is also equal to BC.

Thus, the straight-line AL, equal to the given straight-line BC, has been placed at the given point A. (Which is) the very thing it was required to do.

† This proposition admits of a number of different cases, depending on the relative positions of the point A and the line BC. In such situations, Euclid invariably only considers one particular case—usually, the most difficult—and leaves the remaining cases as exercises for the reader.

γ´.

Δύο δοθεισῶν εὐθειῶν ἀνίσων ἀπὸ τῆς μείζονος τῇ ἐλάσσονι ἴσην εὐθεῖαν ἀφελεῖν.

Ἔστωσαν αἱ δοθεῖσαι δύο εὐθεῖαι ἄνισοι αἱ ΑΒ, Γ, ὧν μείζων ἔστω ἡ ΑΒ· δεῖ δὴ ἀπὸ τῆς μείζονος τῆς ΑΒ τῇ ἐλάσσονι τῇ Γ ἴσην εὐθεῖαν ἀφελεῖν.

Κείσθω πρὸς τῷ Α σημείῳ τῇ Γ εὐθείᾳ ἴση ἡ ΑΔ· καὶ κέντρῳ μὲν τῷ Α διαστήματι δὲ τῷ ΑΔ κύκλος γεγράφθω ὁ ΔΕΖ.

Καὶ ἐπεὶ τὸ Α σημεῖον κέντρον ἐστὶ τοῦ ΔΕΖ κύκλου, ἴση ἐστὶν ἡ ΑΕ τῇ ΑΔ· ἀλλὰ καὶ ἡ Γ τῇ ΑΔ ἐστιν ἴση. ἑκατέρα ἄρα τῶν ΑΕ, Γ τῇ ΑΔ ἐστιν ἴση· ὥστε καὶ ἡ ΑΕ τῇ Γ ἐστιν ἴση.

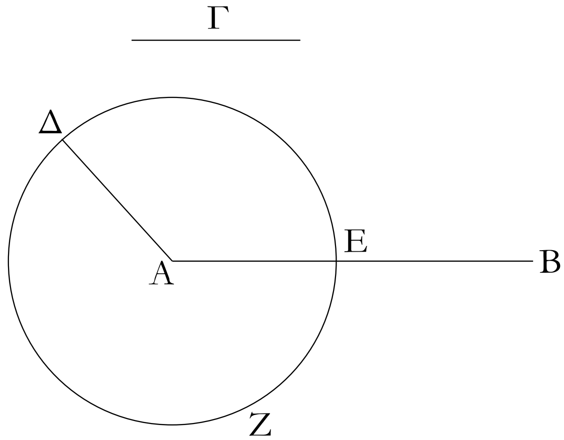
Proposition 3

For two given unequal straight-lines, to cut off from the greater a straight-line equal to the lesser.

Let AB and C be the two given unequal straight-lines, of which let the greater be AB. So it is required to cut off a straight-line equal to the lesser C from the greater AB.

Let the line AD, equal to the straight-line C, have been placed at point A [Prop. 1.2]. And let the circle DEF have been drawn with center A and radius AD [Post. 3].

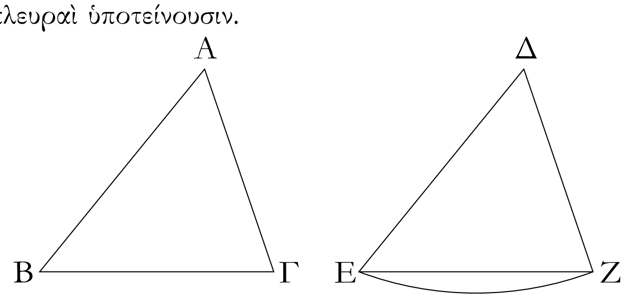
And since point A is the center of circle DEF, AE is equal to AD [Def. 1.15]. But, C is also equal to AD. Thus, AE and C are each equal to AD. So AE is also



Δύο ἄρα δοθεισῶν εὐθειῶν ἀνίσων τῶν ΑΒ, Γ ἀπὸ τῆς μείζονος τῆς ΑΒ τῇ ἐλάσσονι τῇ Γ ἴση ἀφῄρηται ἡ ΑΕ· ὅπερ ἔδει ποιῆσαι.

δ΄.

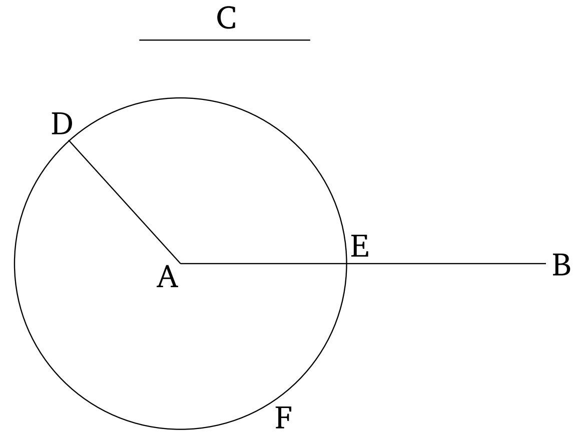
Ἐὰν δύο τρίγωνα τὰς δύο πλευρὰς [ταῖς] δυσὶ πλευραῖς ἴσας ἔχῃ ἑκατέραν ἑκατέρᾳ καὶ τὴν γωνίαν τῇ γωνίᾳ ἴσην ἔχῃ τὴν ὑπὸ τῶν ἴσων εὐθειῶν περιεχομένην, καὶ τὴν βάσιν τῇ βάσει ἴσην ἕξει, καὶ τὸ τρίγωνον τῷ τριγώνῳ ἴσον ἔσται, καὶ αἱ λοιπαὶ γωνίαι ταῖς λοιπαῖς γωνίαις ἴσαι ἔσονται ἑκατέρα ἑκατέρᾳ, ὑφ᾽ ἃς αἱ ἴσαι πλευραὶ ὑποτείνουσιν.



Ἔστω δύο τρίγωνα τὰ ΑΒΓ, ΔΕΖ τὰς δύο πλευρὰς τὰς ΑΒ, ΑΓ ταῖς δυσὶ πλευραῖς ταῖς ΔΕ, ΔΖ ἴσας ἔχοντα ἑκατέραν ἑκατέρᾳ τὴν μὲν ΑΒ τῇ ΔΕ τὴν δὲ ΑΓ τῇ ΔΖ καὶ γωνίαν τὴν ὑπὸ ΒΑΓ γωνίᾳ τῇ ὑπὸ ΕΔΖ ἴσην. λέγω, ὅτι καὶ βάσις ἡ ΒΓ βάσει τῇ ΕΖ ἴση ἐστίν, καὶ τὸ ΑΒΓ τρίγωνον τῷ ΔΕΖ τριγώνῳ ἴσον ἔσται, καὶ αἱ λοιπαὶ γωνίαι ταῖς λοιπαῖς γωνίαις ἴσαι ἔσονται ἑκατέρα ἑκατέρᾳ, ὑφ᾽ ἃς αἱ ἶσαι πλευραὶ ὑποτείνουσιν, ἡ μὲν ὑπὸ ΑΒΓ τῇ ὑπὸ ΔΕΖ, ἡ δὲ ὑπὸ ΑΓΒ τῇ ὑπὸ ΔΖΕ.

Ἐφαρμοζομένου γὰρ τοῦ ΑΒΓ τριγώνου ἐπὶ τὸ ΔΕΖ τρίγωνον καὶ τιθεμένου τοῦ μὲν Α σημείου ἐπὶ τὸ Δ σημεῖον τῆς δὲ ΑΒ εὐθείας ἐπὶ τὴν ΔΕ, ἐφαρμόσει καὶ τὸ Β σημεῖον ἐπὶ τὸ Ε διὰ τὸ ἴσην εἶναι τὴν ΑΒ τῇ ΔΕ· ἐφαρμοσάσης δὴ τῆς ΑΒ ἐπὶ τὴν ΔΕ ἐφαρμόσει

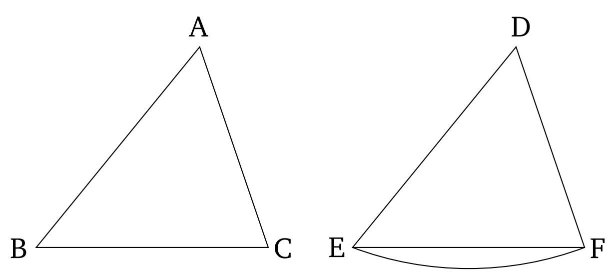
equal to C [C.N. 1].



Thus, for two given unequal straight-lines, AB and C, the (straight-line) AE, equal to the lesser C, has been cut off from the greater AB. (Which is) the very thing it was required to do.

Proposition 4

If two triangles have two corresponding sides equal, and have the angles enclosed by the equal sides equal, then they will also have equal bases, and the two triangles will be equal, and the remaining angles subtended by the equal sides will be equal to the corresponding remaining angles.



Let ABC and DEF be two triangles having the two sides AB and AC equal to the two sides DE and DF, respectively. (That is) AB to DE, and AC to DF. And (let) the angle BAC (be) equal to the angle EDF. I say that the base BC is also equal to the base EF, and triangle ABC will be equal to triangle DEF, and the remaining angles subtended by the equal sides will be equal to the corresponding remaining angles. (That is) ABC to DEF, and ACB to DFE.

Let the triangle ABC be applied to the triangle DEF,[†] the point A being placed on the point D, and the straight-line AB on DE. The point B will also coincide with E, on account of AB being equal to DE. So (because of) AB coinciding with DE, the straight-line καὶ ἡ ΑΓ εὐθεῖα ἐπὶ τὴν ΔΖ διὰ τὸ ἴσην εἶναι τὴν ὑπὸ ΒΑΓ γωνίαν τῇ ὑπὸ ΕΔΖ· ὥστε καὶ τὸ Γ σημεῖον ἐπὶ τὸ Ζ σημεῖον ἐφαρμόσει διὰ τὸ ἴσην πάλιν εἶναι τὴν ΑΓ τῇ ΔΖ. ἀλλὰ μὴν καὶ τὸ Β ἐπὶ τὸ Ε ἐφηρμόκει· ὥστε βάσις ἡ ΒΓ ἐπὶ βάσιν τὴν ΕΖ ἐφαρμόσει. εἰ γὰρ τοῦ μὲν Β ἐπὶ τὸ Ε ἐφαρμόσαντος τοῦ δὲ Γ ἐπὶ τὸ Ζ ἡ ΒΓ βάσις ἐπὶ τὴν ΕΖ οὐκ ἐφαρμόσει, δύο εὐθεῖαι χωρίον περιέξουσιν· ὅπερ ἐστὶν ἀδύνατον. ἐφαρμόσει ἄρα ἡ ΒΓ βάσις ἐπὶ τὴν ΕΖ καὶ ἴση αὐτῇ ἔσται· ὥστε καὶ ὅλον τὸ ΑΒΓ τρίγωνον ἐπὶ ὅλον τὸ ΔΕΖ τρίγωνον ἐφαρμόσει καὶ ἴσον αὐτῷ ἔσται, καὶ αἱ λοιπαὶ γωνίαι ἐπὶ τὰς λοιπὰς γωνίας ἐφαρμόσουσι καὶ ἴσαι αὐταῖς ἔσονται, ἡ μὲν ὑπὸ ΑΒΓ τῇ ὑπὸ ΔΕΖ ἡ δὲ ὑπὸ ΑΓΒ τῇ ὑπὸ ΔΖΕ.

Ἐὰν ἄρα δύο τρίγωνα τὰς δύο πλευρὰς [ταῖς] δύο πλευραῖς ἴσας ἔχῃ ἑκατέραν ἑκατέρᾳ καὶ τὴν γωνίαν τῇ γωνίᾳ ἴσην ἔχῃ τὴν ὑπὸ τῶν ἴσων εὐθειῶν περιεχομένην, καὶ τὴν βάσιν τῇ βάσει ἴσην ἕξει, καὶ τὸ τρίγωνον τῷ τριγώνῳ ἴσον ἔσται, καὶ αἱ λοιπαὶ γωνίαι ταῖς λοιπαῖς γωνίαις ἴσαι ἔσονται ἑκατέρα ἑκατέρᾳ, ὑφ᾽ ἃς αἱ ἴσαι πλευραὶ ὑποτείνουσιν· ὅπερ ἔδει δεῖξαι.

AC will also coincide with DF, on account of the angle BAC being equal to EDF. So the point C will also coincide with the point F, again on account of AC being equal to DF. But, point B certainly also coincided with point E, so that the base BC will coincide with the base EF. For if B coincides with E, and C with F, and the base BC does not coincide with EF, then two straight-lines will encompass an area. The very thing is impossible [Post. 1].‡ Thus, the base BC will coincide with EF, and will be equal to it [C.N. 4]. So the whole triangle ABC will coincide with the whole triangle DEF, and will be equal to it [C.N. 4]. And the remaining angles will coincide with the remaining angles, and will be equal to them [C.N. 4]. (That is) ABC to DEF, and ACB to DFE [C.N. 4].

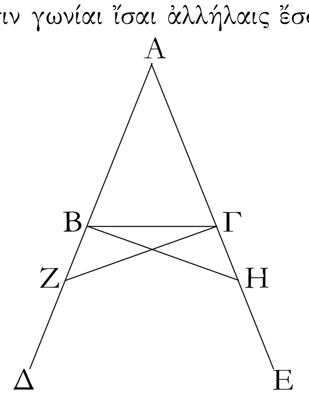
Thus, if two triangles have two corresponding sides equal, and have the angles enclosed by the equal sides equal, then they will also have equal bases, and the two triangles will be equal, and the remaining angles subtended by the equal sides will be equal to the corresponding remaining angles. (Which is) the very thing it was required to show.

† The application of one figure to another should be counted as an additional postulate.

‡ Since Post. 1 implicitly assumes that the straight-line joining two given points is unique.

ε´.

Τῶν ἰσοσκελῶν τριγώνων αἱ πρὸς τῇ βάσει γωνίαι ἴσαι ἀλλήλαις εἰσίν, καὶ προσεκβληθεισῶν τῶν ἴσων εὐθειῶν αἱ ὑπὸ τὴν βάσιν γωνίαι ἴσαι ἀλλήλαις ἔσονται.



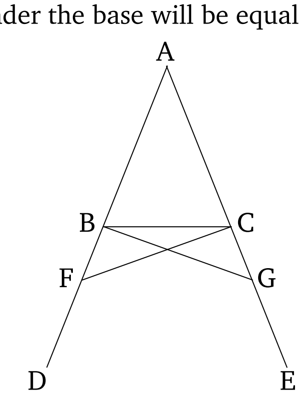
Ἔστω τρίγωνον ἰσοσκελὲς τὸ ΑΒΓ ἴσην ἔχον τὴν ΑΒ πλευρὰν τῇ ΑΓ πλευρᾷ, καὶ προσεκβεβλήσθωσαν ἐπ᾽ εὐθείας ταῖς ΑΒ, ΑΓ εὐθεῖαι αἱ ΒΔ, ΓΕ· λέγω, ὅτι ἡ μὲν ὑπὸ ΑΒΓ γωνία τῇ ὑπὸ ΑΓΒ ἴση ἐστίν, ἡ δὲ ὑπὸ ΓΒΔ τῇ ὑπὸ ΒΓΕ.

Εἰλήφθω γὰρ ἐπὶ τῆς ΒΔ τυχὸν σημεῖον τὸ Ζ, καὶ ἀφῃρήσθω ἀπὸ τῆς μείζονος τῆς ΑΕ τῇ ἐλάσσονι τῇ ΑΖ ἴση ἡ ΑΗ, καὶ ἐπεζεύχθωσαν αἱ ΖΓ, ΗΒ εὐθεῖαι.

Ἐπεὶ οὖν ἴση ἐστὶν ἡ μὲν ΑΖ τῇ ΑΗ ἡ δὲ ΑΒ τῇ

Proposition 5

For isosceles triangles, the angles at the base are equal to one another, and if the equal sides are produced then the angles under the base will be equal to one another.



Let ABC be an isosceles triangle having the side AB equal to the side AC, and let the straight-lines BD and CE have been produced in a straight-line with AB and AC (respectively) [Post. 2]. I say that the angle ABC is equal to ACB, and (angle) CBD to BCE.

For let the point F have been taken somewhere on BD, and let AG have been cut off from the greater AE, equal to the lesser AF [Prop. 1.3]. Also, let the straight-lines FC and GB have been joined [Post. 1].

ΑΓ, δύο δὴ αἱ ΖΑ, ΑΓ δυσὶ ταῖς ΗΑ, ΑΒ ἴσαι εἰσὶν ἑκατέρα ἑκατέρᾳ· καὶ γωνίαν κοινὴν περιέχουσι τὴν ὑπὸ ΖΑΗ· βάσις ἄρα ἡ ΖΓ βάσει τῇ ΗΒ ἴση ἐστίν, καὶ τὸ ΑΖΓ τρίγωνον τῷ ΑΗΒ τριγώνῳ ἴσον ἔσται, καὶ αἱ λοιπαὶ γωνίαι ταῖς λοιπαῖς γωνίαις ἴσαι ἔσονται ἑκατέρα ἑκατέρᾳ, ὑφ᾽ ἃς αἱ ἴσαι πλευραὶ ὑποτείνουσιν, ἡ μὲν ὑπὸ ΑΓΖ τῇ ὑπὸ ΑΒΗ, ἡ δὲ ὑπὸ ΑΖΓ τῇ ὑπὸ ΑΗΒ. καὶ ἐπεὶ ὅλη ἡ ΑΖ ὅλῃ τῇ ΑΗ ἐστιν ἴση, ὧν ἡ ΑΒ τῇ ΑΓ ἐστιν ἴση, λοιπὴ ἄρα ἡ ΒΖ λοιπῇ τῇ ΓΗ ἐστιν ἴση. ἐδείχθη δὲ καὶ ἡ ΖΓ τῇ ΗΒ ἴση· δύο δὴ αἱ ΒΖ, ΖΓ δυσὶ ταῖς ΓΗ, ΗΒ ἰσαι εἰσὶν ἑκατέρα ἑκατέρᾳ· καὶ γωνία ἡ ὑπὸ ΒΖΓ γωνίᾳ τη ὑπὸ ΓΗΒ ἴση, καὶ βάσις αὐτῶν κοινὴ ἡ ΒΓ· καὶ τὸ ΒΖΓ ἄρα τρίγωνον τῷ ΓΗΒ τριγώνῳ ἴσον ἔσται, καὶ αἱ λοιπαὶ γωνίαι ταῖς λοιπαῖς γωνίαις ἴσαι ἔσονται ἑκατέρα ἑκατέρᾳ, ὑφ᾽ ἃς αἱ ἴσαι πλευραὶ ὑποτείνουσιν· ἴση ἄρα ἐστὶν ἡ μὲν ὑπὸ ΖΒΓ τῇ ὑπὸ ΗΓΒ ἡ δὲ ὑπὸ ΒΓΖ τῇ ὑπὸ ΓΒΗ. ἐπεὶ οὖν ὅλη ἡ ὑπὸ ΑΒΗ γωνία ὅλῃ τῇ ὑπὸ ΑΓΖ γωνίᾳ ἐδείχθη ἴση, ὧν ἡ ὑπὸ ΓΒΗ τῇ ὑπὸ ΒΓΖ ἴση, λοιπὴ ἄρα ἡ ὑπὸ ΑΒΓ λοιπῇ τῇ ὑπὸ ΑΓΒ ἐστιν ἴση· καί εἰσι πρὸς τῇ βάσει τοῦ ΑΒΓ τριγώνου. ἐδείχθη δὲ καὶ ἡ ὑπὸ ΖΒΓ τῇ ὑπὸ ΗΓΒ ἴση· καί εἰσιν ὑπὸ τὴν βάσιν.

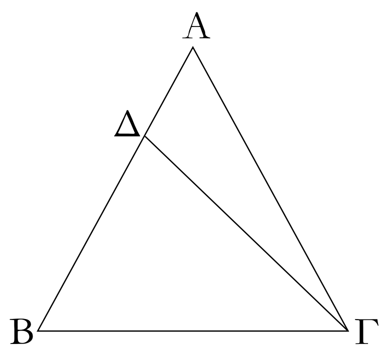
Τῶν ἄρα ἰσοσκελῶν τριγώνων αἱ τρὸς τῇ βάσει γωνίαι ἴσαι ἀλλήλαις εἰσίν, καὶ προσεκβληθεισῶν τῶν ἴσων εὐθειῶν αἱ ὑπὸ τὴν βάσιν γωνίαι ἴσαι ἀλλήλαις ἔσονται· ὅπερ ἔδει δεῖξαι.

In fact, since AF is equal to AG, and AB to AC, the two (straight-lines) FA, AC are equal to the two (straight-lines) GA, AB, respectively. They also encompass a common angle FAG. Thus, the base FC is equal to the base GB, and the triangle AFC will be equal to the triangle AGB, and the remaining angles subtendend by the equal sides will be equal to the corresponding remaining angles [Prop. 1.4]. (That is) ACF to ABG, and AFC to AGB. And since the whole of AF is equal to the whole of AG, within which AB is equal to AC, the remainder BF is thus equal to the remainder CG [C.N. 3]. But FC was also shown (to be) equal to GB. So the two (straight-lines) BF, FC are equal to the two (straight-lines) CG, GB, respectively, and the angle BFC (is) equal to the angle CGB, and the base BC is common to them. Thus, the triangle BFC will be equal to the triangle CGB, and the remaining angles subtended by the equal sides will be equal to the corresponding remaining angles [Prop. 1.4]. Thus, FBC is equal to GCB, and BCF to CBG. Therefore, since the whole angle ABG was shown (to be) equal to the whole angle ACF, within which CBG is equal to BCF, the remainder ABC is thus equal to the remainder ACB [C.N. 3]. And they are at the base of triangle ABC. And FBC was also shown (to be) equal to GCB. And they are under the base.

Thus, for isosceles triangles, the angles at the base are equal to one another, and if the equal sides are produced then the angles under the base will be equal to one another. (Which is) the very thing it was required to show.

ϛ΄.

Ἐὰν τριγώνου αἱ δύο γωνίαι ἴσαι ἀλλήλαις ὦσιν, καὶ αἱ ὑπὸ τὰς ἴσας γωνίας ὑποτείνουσαι πλευραὶ ἴσαι ἀλλήλαις ἔσονται.

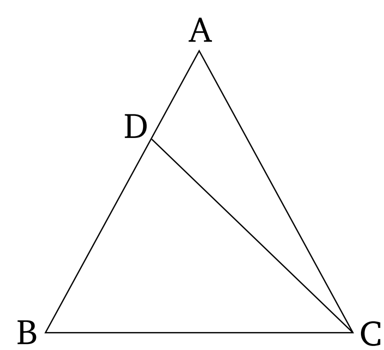


Ἔστω τρίγωνον τὸ ΑΒΓ ἴσην ἔχον τὴν ὑπὸ ΑΒΓ γωνίαν τῇ ὑπὸ ΑΓΒ γωνίᾳ· λέγω, ὅτι καὶ πλευρὰ ἡ ΑΒ πλευρᾷ τῇ ΑΓ ἐστιν ἴση.

Εἰ γὰρ ἄνισός ἐστιν ἡ ΑΒ τῇ ΑΓ, ἡ ἑτέρα αὐτῶν μείζων ἐστίν. ἔστω μείζων ἡ ΑΒ, καὶ ἀφῃρήσθω ἀπὸ

Proposition 6

If a triangle has two angles equal to one another then the sides subtending the equal angles will also be equal to one another.



Let ABC be a triangle having the angle ABC equal to the angle ACB. I say that side AB is also equal to side AC.

For if AB is unequal to AC then one of them is greater. Let AB be greater. And let DB, equal to τῆς μείζονος τῆς ΑΒ τῇ ἐλάττονι τῇ ΑΓ ἴση ἡ ΔΒ, καὶ ἐπεζεύχθω ἡ ΔΓ.

Ἐπεὶ οὖν ἴση ἐστὶν ἡ ΔΒ τῇ ΑΓ κοινὴ δὲ ἡ ΒΓ, δύο δὴ αἱ ΔΒ, ΒΓ δύο ταῖς ΑΓ, ΓΒ ἴσαι εἰσὶν ἑκατέρα ἑκατέρᾳ, καὶ γωνία ἡ ὑπὸ ΔΒΓ γωνιᾳ τῇ ὑπὸ ΑΓΒ ἐστιν ἴση· βάσις ἄρα ἡ ΔΓ βάσει τῇ ΑΒ ἴση ἐστίν, καὶ τὸ ΔΒΓ τρίγωνον τῷ ΑΓΒ τριγώνῳ ἴσον ἔσται, τὸ ἔλασσον τῷ μείζονι· ὅπερ ἄτοπον· οὐκ ἄρα ἄνισός ἐστιν ἡ ΑΒ τῇ ΑΓ· ἴση ἄρα.

Ἐὰν ἄρα τριγώνου αἱ δύο γωνίαι ἴσαι ἀλλήλαις ὦσιν, καὶ αἱ ὑπὸ τὰς ἴσας γωνίας ὑποτείνουσαι πλευραὶ ἴσαι ἀλλήλαις ἔσονται· ὅπερ ἔδει δεῖξαι.

the lesser AC, have been cut off from the greater AB [Prop. 1.3]. And let DC have been joined [Post. 1].

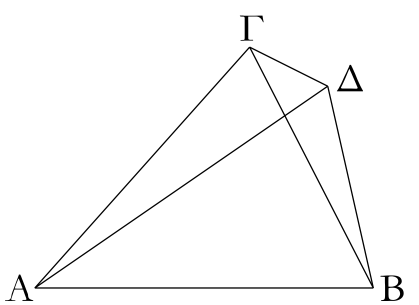
Therefore, since DB is equal to AC, and BC (is) common, the two sides DB, BC are equal to the two sides AC, CB, respectively, and the angle DBC is equal to the angle ACB. Thus, the base DC is equal to the base AB, and the triangle DBC will be equal to the triangle ACB [Prop. 1.4], the lesser to the greater. The very notion (is) absurd [C.N. 5]. Thus, AB is not unequal to AC. Thus, (it is) equal.†

Thus, if a triangle has two angles equal to one another then the sides subtending the equal angles will also be equal to one another. (Which is) the very thing it was required to show.

† Here, use is made of the previously unmentioned common notion that if two quantities are not unequal then they must be equal. Later on, use is made of the closely related common notion that if two quantities are not greater than or less than one another, respectively, then they must be equal to one another.

ζ′.

Ἐπὶ τῆς αὐτῆς εὐθείας δύο ταῖς αὐταῖς εὐθείαις ἄλλαι δύο εὐθεῖαι ἴσαι ἑκατέρα ἑκατέρᾳ οὐ συσταθήσονται πρὸς ἄλλῳ καὶ ἄλλῳ σημείῳ ἐπὶ τὰ αὐτὰ μέρη τὰ αὐτὰ πέρατα ἔχουσαι ταῖς ἐξ ἀρχῆς εὐθείαις.



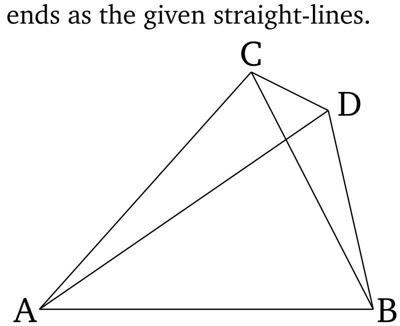
Εἰ γὰρ δυνατόν, ἐπὶ τῆς αὐτῆς εὐθείας τῆς ΑΒ δύο ταῖς αὐταῖς εὐθείαις ταῖς ΑΓ, ΓΒ ἄλλαι δύο εὐθεῖαι αἱ ΑΔ, ΔΒ ἴσαι ἑκατέρα ἑκατερᾳ συνεστάτωσαν πρὸς ἄλλῳ καὶ ἄλλῳ σημείῳ τῷ τε Γ καὶ Δ ἐπὶ τὰ αὐτὰ μέρη τὰ αὐτὰ πέρατα ἔχουσαι, ὥστε ἴσην εἶναι τὴν μὲν ΓΑ τῇ ΔΑ τὸ αὐτὸ πέρας ἔχουσαν αὐτῇ τὸ Α, τὴν δὲ ΓΒ τῇ ΔΒ τὸ αὐτὸ πέρας ἔχουσαν αὐτῇ τὸ Β, καὶ ἐπεζεύχθω ἡ ΓΔ.

Ἐπεὶ οὖν ἴση ἐστὶν ἡ ΑΓ τῇ ΑΔ, ἴση ἐστὶ καὶ γωνία ἡ ὑπὸ ΑΓΔ τῇ ὑπὸ ΑΔΓ· μείζων ἄρα ἡ ὑπὸ ΑΔΓ τῆς ὑπὸ ΔΓΒ· πολλῷ ἄρα ἡ ὑπὸ ΓΔΒ μείζων ἐστί τῆς ὑπὸ ΔΓΒ. πάλιν ἐπεὶ ἴση ἐστὶν ἡ ΓΒ τῇ ΔΒ, ἴση ἐστὶ καὶ γωνία ἡ ὑπὸ ΓΔΒ γωνίᾳ τῇ ὑπὸ ΔΓΒ. ἐδείχθη δὲ αὐτῆς καὶ πολλῷ μείζων· ὅπερ ἐστὶν ἀδύατον.

Οὐκ ἄρα ἐπὶ τῆς αὐτῆς εὐθείας δύο ταῖς αὐταῖς εὐθείαις ἄλλαι δύο εὐθεῖαι ἴσαι ἑκατέρα ἑκατέρᾳ συ-

Proposition 7

On the same straight-line, two other straight-lines equal, respectively, to two (given) straight-lines (which meet) cannot be constructed (meeting) at a different point on the same side (of the straight-line), but having the same ends as the given straight-lines.



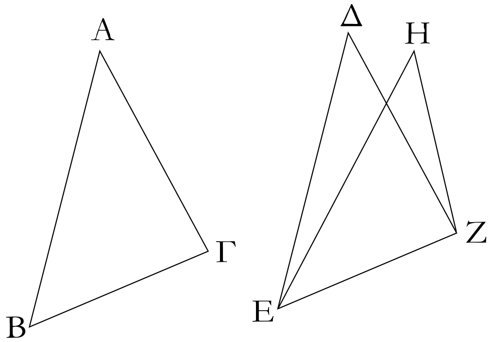
For, if possible, let the two straight-lines AD, DB, equal to two (given) straight-lines AC, CB, respectively, have been constructed on the same straight-line AB, meeting at different points, C and D, on the same side (of AB), and having the same ends (on AB). So CA and DA are equal, having the same ends at A, and CB and DB are equal, having the same ends at B. And let CD have been joined [Post. 1].

Therefore, since AC is equal to AD, the angle ACD is also equal to angle ADC [Prop. 1.5]. Thus, ADC (is) greater than DCB [C.N. 5]. Thus, CDB is much greater than DCB [C.N. 5]. Again, since CB is equal to DB, the angle CDB is also equal to angle DCB [Prop. 1.5]. But it was shown that the former (angle) is also much greater (than the latter). The very thing is impossible.

Thus, on the same straight-line, two other straightσταθήσονται πρὸς ἄλλῳ καὶ ἄλλῳ σημείῳ ἐπὶ τὰ αὐτὰ μέρη τὰ αὐτὰ πέρατα ἔχουσαι ταῖς ἐξ ἀρχῆς εὐθείαις· ὅπερ ἔδει δεῖξαι.

η΄.

Ἐὰν δύο τρίγωνα τὰς δύο πλευρὰς [ταῖς] δύο πλευραῖς ἴσας ἔχῃ ἑκατέραν ἑκατέρᾳ, ἔχῃ δὲ καὶ τὴν βάσιν τῇ βάσει ἴσην, καὶ τὴν γωνίαν τῇ γωνίᾳ ἴσην ἕξει τὴν ὑπὸ τῶν ἴσων εὐθειῶν περιεχομένην.



Ἔστω δύο τρίγωνα τὰ ΑΒΓ, ΔΕΖ τὰς δύο πλευρὰς τὰς ΑΒ, ΑΓ ταῖς δύο πλευραῖς ταῖς ΔΕ, ΔΖ ἴσας ἔχοντα ἑκατέραν ἑκατέρᾳ, τὴν μὲν ΑΒ τῇ ΔΕ τὴν δὲ ΑΓ τῇ ΔΖ· ἐχέτω δὲ καὶ βάσιν τὴν ΒΓ βάσει τῇ ΕΖ ἴσην· λέγω, ὅτι καὶ γωνία ἡ ὑπὸ ΒΑΓ γωνίᾳ τῇ ὑπὸ ΕΔΖ ἐστιν ἴση.

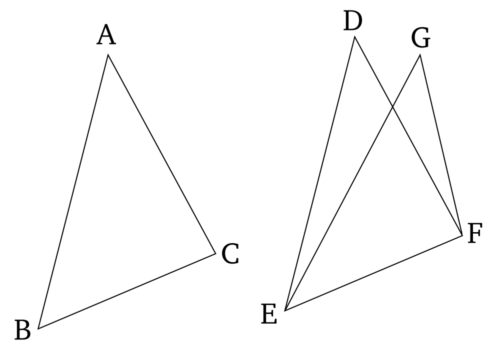
Ἐφαρμοζομένου γὰρ τοῦ ΑΒΓ τριγώνου ἐπὶ τὸ ΔΕΖ τρίγωνον καὶ τιθεμένου τοῦ μὲν Β σημείου ἐπὶ τὸ Ε σημεῖον τῆς δὲ ΒΓ εὐθείας ἐπὶ τὴν ΕΖ ἐφαρμόσει καὶ τὸ Γ σημεῖον ἐπὶ τὸ Ζ διὰ τὸ ἴσην εἶναι τὴν ΒΓ τῇ ΕΖ· ἐφαρμοσάσης δὴ τῆς ΒΓ ἐπὶ τὴν ΕΖ ἐφαρμόσουσι καὶ αἱ ΒΑ, ΓΑ ἐπὶ τὰς ΕΔ, ΔΖ. εἰ γὰρ βάσις μὲν ἡ ΒΓ ἐπὶ βάσιν τὴν ΕΖ ἐφαρμόσει, αἱ δὲ ΒΑ, ΑΓ πλευραὶ ἐπὶ τὰς ΕΔ, ΔΖ οὐκ ἐφαρμόσουσιν ἀλλὰ παραλλάξουσιν ὡς αἱ ΕΗ, ΗΖ, συσταθήσονται ἐπὶ τῆς αὐτῆς εὐθείας δύο ταῖς αὐταῖς εὐθείαις ἄλλαι δύο εὐθεῖαι ἴσαι ἑκατέρα ἑκατέρᾳ πρὸς ἄλλῳ καὶ ἄλλῳ σημείῳ ἐπὶ τὰ αὐτὰ μέρη τὰ αὐτὰ πέρατα ἔχουσαι. οὐ συνίστανται δέ· οὐκ ἄρα ἐφαρμοζομένης τῆς ΒΓ βάσεως ἐπὶ τὴν ΕΖ βάσιν οὐκ ἐφαρμόσουσι καὶ αἱ ΒΑ, ΑΓ πλευραὶ ἐπὶ τὰς ΕΔ, ΔΖ. ἐφαρμόσουσιν ἄρα· ὥστε καὶ γωνία ἡ ὑπὸ ΒΑΓ ἐπὶ γωνίαν τὴν ὑπὸ ΕΔΖ ἐφαρμόσει καὶ ἴση αὐτῇ ἔσται.

Ἐὰν ἄρα δύο τρίγωνα τὰς δύο πλευρὰς [ταῖς] δύο πλευραῖς ἴσας ἔχῃ ἑκατέραν ἑκατέρᾳ καὶ τὴν βάσιν τῇ βάσει ἴσην ἔχῃ, καὶ τὴν γωνίαν τῇ γωνίᾳ ἴσην ἕξει τὴν ὑπὸ τῶν ἴσων εὐθειῶν περιεχομένην· ὅπερ ἔδει δεῖξαι.

lines equal, respectively, to two (given) straight-lines (which meet) cannot be constructed (meeting) at a different point on the same side (of the straight-line), but having the same ends as the given straight-lines. (Which is) the very thing it was required to show.

Proposition 8

If two triangles have two corresponding sides equal, and also have equal bases, then the angles encompassed by the equal straight-lines will also be equal.



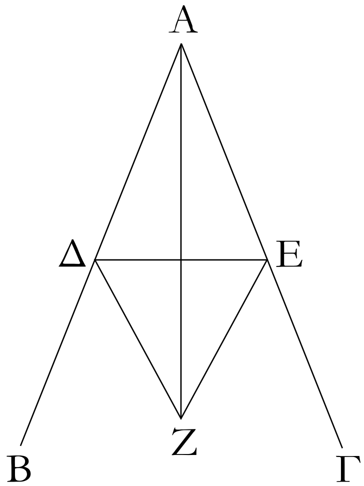
Let ABC and DEF be two triangles having the two sides AB and AC equal to the two sides DE and DF, respectively. (That is) AB to DE, and AC to DF. Let them also have the base BC equal to the base EF. I say that the angle BAC is also equal to the angle EDF.

For if triangle ABC is applied to triangle DEF, the point B being placed on point E, and the straight-line BC on EF, point C will also coincide with F, on account of BC being equal to EF. So (because of) BC coinciding with EF, (the sides) BA and CA will also coincide with ED and DF (respectively). For if base BC coincides with base EF, but the sides AB and AC do not coincide with ED and DF (respectively), but miss like EG and GF (in the above figure), then we will have constructed upon the same straight-line, two other straight-lines equal, respectively, to two (given) straight-lines, and (meeting) at a different point on the same side (of the straight-line), but having the same ends. But (such straight-lines) cannot be constructed [Prop. 1.7]. Thus, the base BC being applied to the base EF, the sides BA and AC cannot not coincide with ED and DF (respectively). Thus, they will coincide. So the angle BAC will also coincide with angle EDF, and they will be equal [C.N. 4].

Thus, if two triangles have two corresponding sides equal, and have equal bases, then the angles encompassed by the equal straight-lines will also be equal. (Which is) the very thing it was required to show.

ϑ´.

Τὴν δοθεῖσαν γωνίαν εὐθύγραμμον δίχα τεμεῖν.



Ἔστω ἡ δοθεῖσα γωνία εὐθύγραμμος ἡ ὑπὸ ΒΑΓ. δεῖ δὴ αὐτὴν δίχα τεμεῖν.

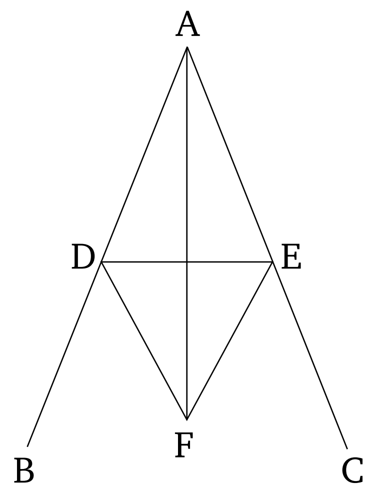
Εἰλήφθω ἐπὶ τῆς ΑΒ τυχὸν σημεῖον τὸ Δ, καὶ ἀφῃρήσθω ἀπὸ τῆς ΑΓ τῇ ΑΔ ἴση ἡ ΑΕ, καὶ ἐπεζεύχθω ἡ ΔΕ, καὶ συνεστάτω ἐπὶ τῆς ΔΕ τρίγωνον ἰσόπλευρον τὸ ΔΕΖ, καὶ ἐπεζεύχθω ἡ ΑΖ· λέγω, ὅτι ἡ ὑπὸ ΒΑΓ γωνία δίχα τέτμηται ὑπὸ τῆς ΑΖ εὐθείας.

Ἐπεὶ γὰρ ἴση ἐστὶν ἡ ΑΔ τῇ ΑΕ, κοινὴ δὲ ἡ ΑΖ, δύο δὴ αἱ ΔΑ, ΑΖ δυσὶ ταῖς ΕΑ, ΑΖ ἴσαι εἰσὶν ἑκατέρα ἑκατέρᾳ. καὶ βάσις ἡ ΔΖ βάσει τῇ ΕΖ ἴση ἐστίν· γωνία ἄρα ἡ ὑπὸ ΔΑΖ γωνίᾳ τῇ ὑπὸ ΕΑΖ ἴση ἐστίν.

Ἡ ἄρα δοθεῖσα γωνία εὐθύγραμμος ἡ ὑπὸ ΒΑΓ δίχα τέτμηται ὑπὸ τῆς ΑΖ εὐθείας· ὅπερ ἔδει ποιῆσαι.

Proposition 9

To cut a given rectilinear angle in half.



Let BAC be the given rectilinear angle. So it is required to cut it in half.

Let the point D have been taken somewhere on AB, and let AE, equal to AD, have been cut off from AC [Prop. 1.3], and let DE have been joined. And let the equilateral triangle DEF have been constructed upon DE [Prop. 1.1], and let AF have been joined. I say that the angle BAC has been cut in half by the straight-line AF.

For since AD is equal to AE, and AF is common, the two (straight-lines) DA, AF are equal to the two (straight-lines) EA, AF, respectively. And the base DF is equal to the base EF. Thus, angle DAF is equal to angle EAF [Prop. 1.8].

Thus, the given rectilinear angle BAC has been cut in half by the straight-line AF. (Which is) the very thing it was required to do.

ι´.

Τὴν δοθεῖσαν εὐθεῖαν πεπερασμένην δίχα τεμεῖν.

Ἔστω ἡ δοθεῖσα εὐθεῖα πεπερασμένη ἡ ΑΒ· δεῖ δὴ τὴν ΑΒ εὐθεῖαν πεπερασμένην δίχα τεμεῖν.

Συνεστάτω ἐπ᾽ αὐτῆς τρίγωνον ἰσόπλευρον τὸ ΑΒΓ, καὶ τετμήσθω ἡ ὑπὸ ΑΓΒ γωνία δίχα τῇ ΓΔ εὐθείᾳ· λέγω, ὅτι ἡ ΑΒ εὐθεῖα δίχα τέτμηται κατὰ τὸ Δ σημεῖον.

Ἐπεὶ γὰρ ἴση ἐστὶν ἡ ΑΓ τῇ ΓΒ, κοινὴ δὲ ἡ ΓΔ, δύο δὴ αἱ ΑΓ, ΓΔ δύο ταῖς ΒΓ, ΓΔ ἴσαι εἰσὶν ἑκατέρα ἑκατέρᾳ· καὶ γωνία ἡ ὑπὸ ΑΓΔ γωνίᾳ τῇ ὑπὸ ΒΓΔ ἴση ἐστίν· βάσις ἄρα ἡ ΑΔ βάσει τῇ ΒΔ ἴση ἐστίν.

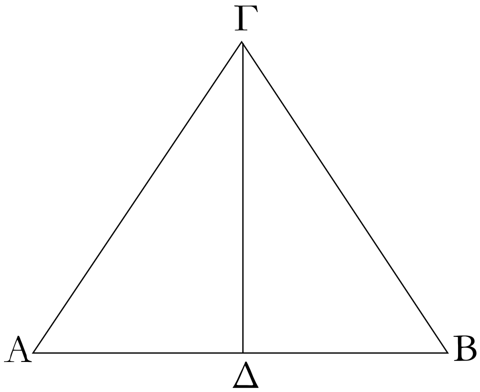
Proposition 10

To cut a given finite straight-line in half.

Let AB be the given finite straight-line. So it is required to cut the finite straight-line AB in half.

Let the equilateral triangle ABC have been constructed upon (AB) [Prop. 1.1], and let the angle ACB have been cut in half by the straight-line CD [Prop. 1.9]. I say that the straight-line AB has been cut in half at point D.

For since AC is equal to CB, and CD (is) common, the two (straight-lines) AC, CD are equal to the two (straight-lines) BC, CD, respectively. And the angle ACD is equal to the angle BCD. Thus, the base AD is equal to the base BD [Prop. 1.4].



Ἡ ἄρα δοθεῖσα εὐθεῖα πεπερασμένη ἡ ΑΒ δίχα τέτμηται κατὰ τὸ Δ· ὅπερ ἔδει ποιῆσαι.

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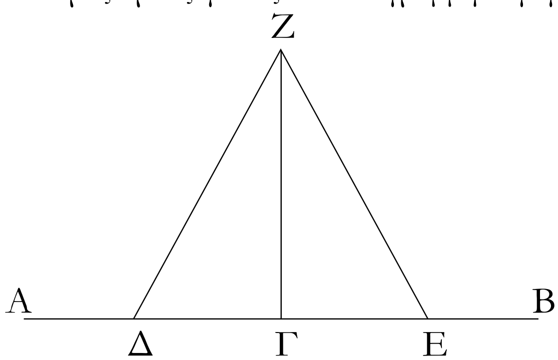
ΠΤῇ δοθείσῃ εὐθείᾳ ἀπὸ τοῦ πρὸς αὐτῃ δοθέντος σημείου πρὸς ὀρθὰς γωνίας εὐθεῖαν γραμμὴν ἀγαγεῖν.

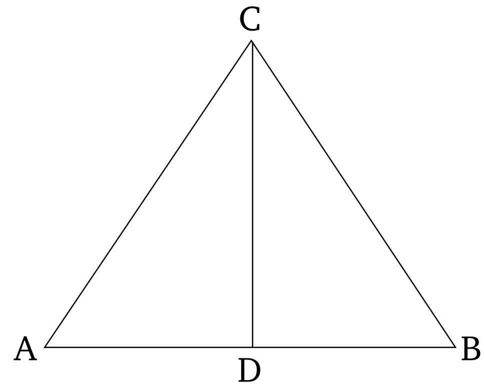


Ἔστω ἡ μὲν δοθεῖσα εὐθεῖα ἡ ΑΒ τὸ δὲ δοθὲν σημεῖον ἐπ᾿ αὐτῆς τὸ Γ· δεῖ δὴ ἀπὸ τοῦ Γ σημείου τῇ ΑΒ εὐθείᾳ πρὸς ὀρθὰς γωνίας εὐθεῖαν γραμμὴν ἀγαγεῖν.

Εἰλήφθω ἐπὶ τῆς ΑΓ τυχὸν σημεῖον τὸ Δ, καὶ κείσθω τῇ ΓΔ ἴση ἡ ΓΕ, καὶ συνεστάτω ἐπὶ τῆς ΔΕ τρίγωνον ἰσόπλευρον τὸ ΖΔΕ, καὶ ἐπεζεύχθω ἡ ΖΓ· λέγω, ὅτι τῇ δοθείσῃ εὐθείᾳ τῇ ΑΒ ἀπὸ τοῦ πρὸς αὐτῇ δοθέντος σημείου τοῦ Γ πρὸς ὀρθὰς γωνίας εὐθεῖα γραμμὴ ἦκται ἡ ΖΓ.

Ἐπεὶ γὰρ ἴση ἐστὶν ἡ ΔΓ τῇ ΓΕ, κοινὴ δὲ ἡ ΓΖ, δύο δὴ αἱ ΔΓ, ΓΖ δυσὶ ταῖς ΕΓ, ΓΖ ἴσαι εἰσὶν ἑκατέρα ἑκατέρᾳ· καὶ βάσις ἡ ΔΖ βάσει τῇ ΖΕ ἴση ἐστίν· γωνία ἄρα ἡ ὑπὸ ΔΓΖ γωνίᾳ τῇ ὑπὸ ΕΓΖ ἴση ἐστίν· καί εἰσιν ἐφεξῆς. ὅταν δὲ εὐθεῖα ἐπ᾿ εὐθεῖαν σταθεῖσα τὰς ἐφεξῆς γωνίας ἴσας ἀλλήλαις ποιῇ, ὀρθὴ ἑκατέρα τῶν ἴσων γωνιῶν ἐστιν· ὀρθὴ ἄρα ἐστὶν ἑκατέρα τῶν ὑπὸ ΔΓΖ, ΖΓΕ.

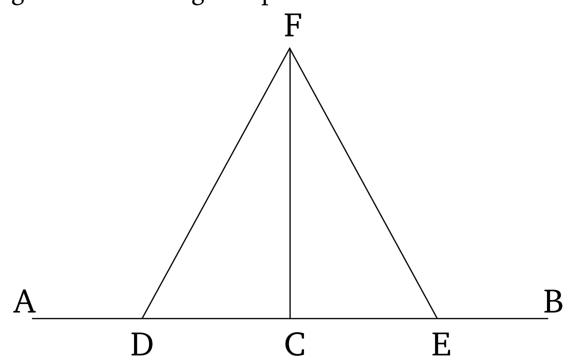
Τῇ ἄρα δοθείσῃ εὐθείᾳ τῇ ΑΒ ἀπὸ τοῦ πρὸς αὐτῇ δοθέντος σημείου τοῦ Γ πρὸς ὀρθὰς γωνίας εὐθεῖα γραμμὴ ἦκται ἡ ΓΖ· ὅπερ ἔδει ποιῆσαι.



Thus, the given finite straight-line AB has been cut in half at (point) D. (Which is) the very thing it was required to do.

Proposition 11

To draw a straight-line at right-angles to a given straight-line from a given point on it.



Let AB be the given straight-line, and C the given point on it. So it is required to draw a straight-line from the point C at right-angles to the straight-line AB.

Let the point D be have been taken somewhere on AC, and let CE be made equal to CD [Prop. 1.3], and let the equilateral triangle FDE have been constructed on DE [Prop. 1.1], and let FC have been joined. I say that the straight-line FC has been drawn at right-angles to the given straight-line AB from the given point C on it.

For since DC is equal to CE, and CF is common, the two (straight-lines) DC, CF are equal to the two (straight-lines), EC, CF, respectively. And the base DF is equal to the base FE. Thus, the angle DCF is equal to the angle ECF [Prop. 1.8], and they are adjacent. But when a straight-line stood on a(nother) straight-line makes the adjacent angles equal to one another, each of the equal angles is a right-angle [Def. 1.10]. Thus, each of the (angles) DCF and FCE is a right-angle.

Thus, the straight-line CF has been drawn at right-

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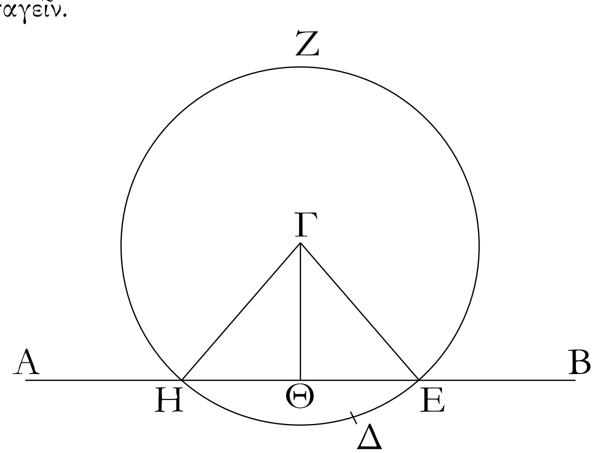
Ἐπὶ τὴν δοθεῖσαν εὐθεῖαν ἄπειρον ἀπὸ τοῦ δοθέντος σημείου, ὃ μή ἐστιν ἐπ᾽ αὐτῆς, κάθετον εὐθεῖαν γραμμὴν ἀγαγεῖν.



Ἔστω ἡ μὲν δοθεῖσα εὐθεῖα ἄπειρος ἡ ΑΒ τὸ δὲ δοθὲν σημεῖον, ὃ μή ἐστιν ἐπ᾽ αὐτῆς, τὸ Γ· δεῖ δὴ ἐπὶ τὴν δοθεῖσαν εὐθεῖαν ἄπειρον τὴν ΑΒ ἀπὸ τοῦ δοθέντος σημείου τοῦ Γ, ὃ μή ἐστιν ἐπ᾽ αὐτῆς, κάθετον εὐθεῖαν γραμμὴν ἀγαγεῖν.

Εἰλήφθω γὰρ ἐπὶ τὰ ἕτερα μέρη τῆς ΑΒ εὐθείας τυχὸν σημεῖον τὸ Δ, καὶ κέντρῳ μὲν τῷ Γ διαστήματι δὲ τῷ ΓΔ κύκλος γεγράφθω ὁ ΕΖΗ, καὶ τετμήσθω ἡ ΕΗ εὐθεῖα δίχα κατὰ τὸ Θ, καὶ ἐπεζεύχθωσαν αἱ ΓΗ, ΓΘ, ΓΕ εὐθεῖαι· λέγω, ὅτι ἐπὶ τὴν δοθεῖσαν εὐθεῖαν ἄπειρον τὴν ΑΒ ἀπὸ τοῦ δοθέντος σημείου τοῦ Γ, ὃ μή ἐστιν ἐπ᾽ αὐτῆς, κάθετος ἦκται ἡ ΓΘ.

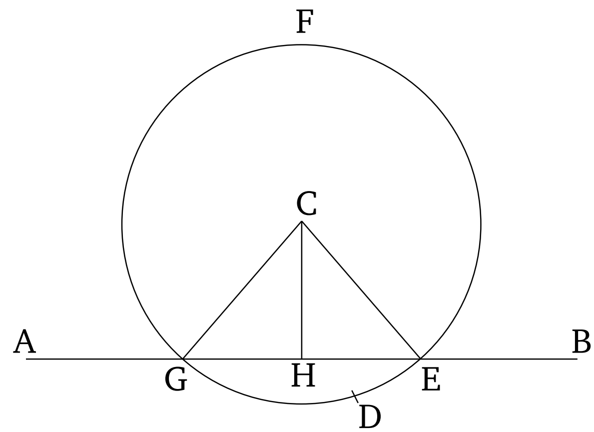
Ἐπεὶ γὰρ ἴση ἐστὶν ἡ ΗΘ τῇ ΘΕ, κοινὴ δὲ ἡ ΘΓ, δύο δὴ αἱ ΗΘ, ΘΓ δύο ταῖς ΕΘ, ΘΓ ἴσαι εἰσὶν ἑκατέρα ἑκατέρᾳ· καὶ βάσις ἡ ΓΗ βάσει τῇ ΓΕ ἐστιν ἴση· γωνία ἄρα ἡ ὑπὸ ΓΘΗ γωνίᾳ τῇ ὑπὸ ΕΘΓ ἐστιν ἴση. καί εἰσιν ἐφεξῆς. ὅταν δὲ εὐθεῖα ἐπ᾽ εὐθεῖαν σταθεῖσα τὰς ἐφεξῆς γωνίας ἴσας ἀλλήλαις ποιῇ, ὀρθὴ ἑκατέρα τῶν ἴσων γωνιῶν ἐστιν, καὶ ἡ ἐφεστηκυῖα εὐθεῖα κάθετος καλεῖται ἐφ᾽ ἣν ἐφέστηκεν.

Ἐπὶ τὴν δοθεῖσαν ἄρα εὐθεῖαν ἄπειρον τὴν ΑΒ ἀπὸ τοῦ δοθέντος σημείου τοῦ Γ, ὃ μή ἐστιν ἐπ᾽ αὐτῆς, κάθετος ἦκται ἡ ΓΘ· ὅπερ ἔδει ποιῆσαι.

angles to the given straight-line AB from the given point C on it. (Which is) the very thing it was required to do.

Proposition 12

To draw a straight-line perpendicular to a given infinite straight-line from a given point which is not on it.



Let AB be the given infinite straight-line and C the given point, which is not on (AB). So it is required to draw a straight-line perpendicular to the given infinite straight-line AB from the given point C, which is not on (AB).

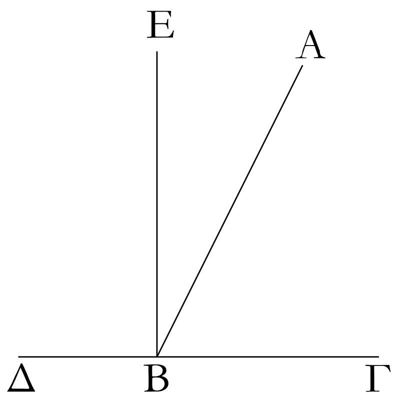
For let point D have been taken somewhere on the other side (to C) of the straight-line AB, and let the circle EFG have been drawn with center C and radius CD [Post. 3], and let the straight-line EG have been cut in half at (point) H [Prop. 1.10], and let the straight-lines CG, CH, and CE have been joined. I say that a (straight-line) CH has been drawn perpendicular to the given infinite straight-line AB from the given point C, which is not on (AB).

For since GH is equal to HE, and HC (is) common, the two (straight-lines) GH, HC are equal to the two straight-lines EH, HC, respectively, and the base CG is equal to the base CE. Thus, the angle CHG is equal to the angle EHC [Prop. 1.8], and they are adjacent. But when a straight-line stood on a(nother) straight-line makes the adjacent angles equal to one another, each of the equal angles is a right-angle, and the former straight-line is called perpendicular to that upon which it stands [Def. 1.10].

Thus, the (straight-line) CH has been drawn perpendicular to the given infinite straight-line AB from the given point C, which is not on (AB). (Which is) the very thing it was required to do.

ιγ΄.

Ἐὰν εὐθεῖα ἐπ᾿ εὐθεῖαν σταθεῖσα γωνίας ποιῇ, ἤτοι δύο ὀρθὰς ἢ δυσὶν ὀρθαῖς ἴσας ποιήσει.



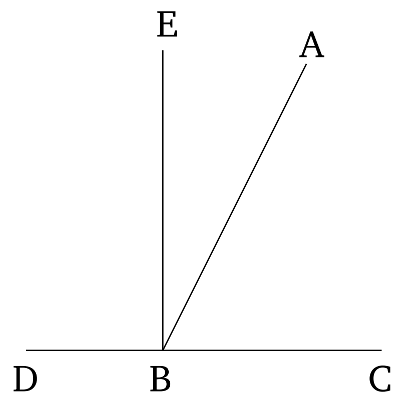
Εὐθεῖα γάρ τις ἡ ΑΒ ἐπ᾿ εὐθεῖαν τὴν ΓΔ σταθεῖσα γωνίας ποιείτω τὰς ὑπὸ ΓΒΑ, ΑΒΔ· λὲγω, ὅτι αἱ ὑπὸ ΓΒΑ, ΑΒΔ γωνίαι ἤτοι δύο ὀρθαί εἰσιν ἢ δυσὶν ὀρθαῖς ἴσαι.

Εἰ μὲν οὖν ἴση ἐστὶν ἡ ὑπὸ ΓΒΑ τῇ ὑπὸ ΑΒΔ, δύο ὀρθαί εἰσιν. εἰ δὲ οὔ, ἤχθω ἀπὸ τοῦ Β σημείου τῇ ΓΔ [εὐθείᾳ] πρὸς ὀρθὰς ἡ ΒΕ· αἱ ἄρα ὑπὸ ΓΒΕ, ΕΒΔ δύο ὀρθαί εἰσιν· καὶ ἐπεὶ ἡ ὑπὸ ΓΒΕ δυσὶ ταῖς ὑπὸ ΓΒΑ, ΑΒΕ ἴση ἐστίν, κοινὴ προσκείσθω ἡ ὑπὸ ΕΒΔ· αἱ ἄρα ὑπὸ ΓΒΕ, ΕΒΔ τρισὶ ταῖς ὑπὸ ΓΒΑ, ΑΒΕ, ΕΒΔ ἴσαι εἰσίν. πάλιν, ἐπεὶ ἡ ὑπὸ ΔΒΑ δυσὶ ταῖς ὑπὸ ΔΒΕ, ΕΒΑ ἴση ἐστίν, κοινὴ προσκείσθω ἡ ὑπὸ ΑΒΓ· αἱ ἄρα ὑπό ΔΒΑ, ΑΒΓ τρισὶ ταῖς ὑπὸ ΔΒΕ, ΕΒΑ, ΑΒΓ ἴσαι εἰσίν. ἐδείχθησαν δὲ καὶ αἱ ὑπὸ ΓΒΕ, ΕΒΔ τρισὶ ταῖς αὐταῖς ἴσαι· τὰ δὲ τῷ αὐτῷ ἴσα καὶ ἀλλήλοις ἐστὶν ἴσα· καὶ αἱ ὑπὸ ΓΒΕ, ΕΒΔ ἄρα ταῖς ὑπὸ ΔΒΑ, ΑΒΓ ἴσαι εἰσίν· ἀλλὰ αἱ ὑπὸ ΓΒΕ, ΕΒΔ δύο ὀρθαί εἰσιν· καὶ αἱ ὑπὸ ΔΒΑ, ΑΒΓ ἄρα δυσὶν ὀρθαῖς ἴσαι εἰσίν.

Ἐὰν ἄρα εὐθεῖα ἐπ᾿ εὐθεῖαν σταθεῖσα γωνίας ποιῇ, ἤτοι δύο ὀρθὰς ἢ δυσὶν ὀρθαῖς ἴσας ποιήσει· ὅπερ ἔδει δεῖξαι.

Proposition 13

If a straight-line stood on a(nother) straight-line makes angles, it will certainly either make two right-angles, or (angles whose sum is) equal to two right-angles.



For let some straight-line AB stood on the straight-line CD make the angles CBA and ABD. I say that the angles CBA and ABD are certainly either two right-angles, or (have a sum) equal to two right-angles.

In fact, if CBA is equal to ABD then they are two right-angles [Def. 1.10]. But, if not, let BE have been drawn from the point B at right-angles to [the straight-line] CD [Prop. 1.11]. Thus, CBE and EBD are two right-angles. And since CBE is equal to the two (angles) CBA and ABE, let EBD have been added to both. Thus, the (sum of the angles) CBE and EBD is equal to the (sum of the) three (angles) CBA, ABE, and EBD [C.N. 2]. Again, since DBA is equal to the two (angles) DBE and EBA, let ABC have been added to both. Thus, the (sum of the angles) DBA and ABC is equal to the (sum of the) three (angles) DBE, EBA, and ABC [C.N. 2]. But (the sum of) CBE and EBD was also shown (to be) equal to the (sum of the) same three (angles). And things equal to the same thing are also equal to one another [C.N. 1]. Therefore, (the sum of) CBE and EBD is also equal to (the sum of) DBA and ABC. But, (the sum of) CBE and EBD is two right-angles. Thus, (the sum of) ABD and ABC is also equal to two right-angles.

Thus, if a straight-line stood on a(nother) straight-line makes angles, it will certainly either make two right-angles, or (angles whose sum is) equal to two right-angles. (Which is) the very thing it was required to show.

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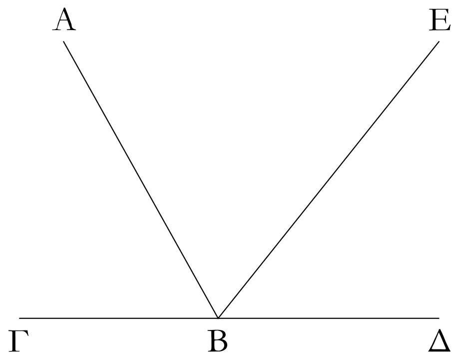
Ἐὰν πρός τινι εὐθείᾳ καὶ τῷ πρὸς αὐτῇ σημείῳ δύο εὐθεῖαι μὴ ἐπὶ τὰ αὐτὰ μέρη κείμεναι τὰς ἐφεξῆς γωνίας

Proposition 14

If two straight-lines, not lying on the same side, make adjacent angles (whose sum is) equal to two right-angles δυσὶν ὀρθαῖς ἴσας ποιῶσιν, ἐπ᾿ εὐθείας ἔσονται ἀλλήλαις αἱ εὐθεῖαι.



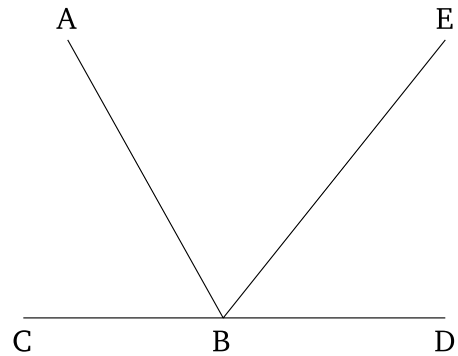
Πρὸς γάρ τινι εὐθείᾳ τῇ ΑΒ καὶ τῷ πρὸς αὐτῇ σημείῳ τῷ Β δύο εὐθεῖαι αἱ ΒΓ, ΒΔ μὴ ἐπὶ τὰ αὐτὰ μέρη κείμεναι τὰς ἐφεξῆς γωνίας τὰς ὑπὸ ΑΒΓ, ΑΒΔ δύο ὀρθαῖς ἴσας ποιείτωσαν· λέγω, ὅτι ἐπ᾿ εὐθείας ἐστὶ τῇ ΓΒ ἡ ΒΔ.

Εἰ γὰρ μή ἐστι τῇ ΒΓ ἐπ᾿ εὐθείας ἡ ΒΔ, ἔστω τῇ ΓΒ ἐπ᾿ εὐθείας ἡ ΒΕ.

Ἐπεὶ οὖν εὐθεῖα ἡ ΑΒ ἐπ᾿ εὐθεῖαν τὴν ΓΒΕ ἐφέστηκεν, αἱ ἄρα ὑπὸ ΑΒΓ, ΑΒΕ γωνίαι δύο ὀρθαῖς ἴσαι εἰσίν· εἰσὶ δὲ καὶ αἱ ὑπὸ ΑΒΓ, ΑΒΔ δύο ὀρθαῖς ἴσαι· αἱ ἄρα ὑπὸ ΓΒΑ, ΑΒΕ ταῖς ὑπὸ ΓΒΑ, ΑΒΔ ἴσαι εἰσίν. κοινὴ ἀφῃρήσθω ἡ ὑπὸ ΓΒΑ· λοιπὴ ἄρα ἡ ὑπὸ ΑΒΕ λοιπῇ τῇ ὑπὸ ΑΒΔ ἐστιν ἴση, ἡ ἐλάσσων τῇ μείζονι· ὅπερ ἐστὶν ἀδύνατον. οὐκ ἄρα ἐπ᾿ εὐθείας ἐστὶν ἡ ΒΕ τῇ ΓΒ. ὁμοίως δὴ δείξομεν, ὅτι οὐδὲ ἄλλη τις πλὴν τῆς ΒΔ· ἐπ᾿ εὐθείας ἄρα ἐστὶν ἡ ΓΒ τῇ ΒΔ.

Ἐὰν ἄρα πρός τινι εὐθείᾳ καὶ τῷ πρὸς αὐτῇ σημείῳ δύο εὐθεῖαι μὴ ἐπὶ αὐτὰ μέρη κείμεναι τὰς ἐφεξῆς γωνίας δυσὶν ὀρθαῖς ἴσας ποιῶσιν, ἐπ᾿ εὐθείας ἔσονται ἀλλήλαις αἱ εὐθεῖαι· ὅπερ ἔδει δεῖξαι.

at the same point on some straight-line, then the two straight-lines will be straight-on (with respect) to one another.



For let two straight-lines BC and BD, not lying on the same side, make adjacent angles ABC and ABD (whose sum is) equal to two right-angles at the same point B on some straight-line AB. I say that BD is straight-on with respect to CB.

For if BD is not straight-on to BC then let BE be straight-on to CB.

Therefore, since the straight-line AB stands on the straight-line CBE, the (sum of the) angles ABC and ABE is thus equal to two right-angles [Prop. 1.13]. But (the sum of) ABC and ABD is also equal to two right-angles. Thus, (the sum of angles) CBA and ABE is equal to (the sum of angles) CBA and ABD [C.N. 1]. Let (angle) CBA have been subtracted from both. Thus, the remainder ABE is equal to the remainder ABD [C.N. 3], the lesser to the greater. The very thing is impossible. Thus, BE is not straight-on with respect to CB. Similarly, we can show that neither (is) any other (straight-line) than BD. Thus, CB is straight-on with respect to BD.

Thus, if two straight-lines, not lying on the same side, make adjacent angles (whose sum is) equal to two right-angles at the same point on some straight-line, then the two straight-lines will be straight-on (with respect) to one another. (Which is) the very thing it was required to show.

ιε′.

Ἐὰν δύο εὐθεῖαι τέμνωσιν ἀλλήλας, τὰς κατὰ κορυφὴν γωνίας ἴσας ἀλλήλαις ποιοῦσιν.

Δύο γὰρ εὐθεῖαι αἱ ΑΒ, ΓΔ τεμνέτωσαν ἀλλήλας κατὰ τὸ Ε σημεῖον· λέγω, ὅτι ἴση ἐστὶν ἡ μὲν ὑπὸ ΑΕΓ γωνία τῇ ὑπὸ ΔΕΒ, ἡ δὲ ὑπὸ ΓΕΒ τῇ ὑπὸ ΑΕΔ.

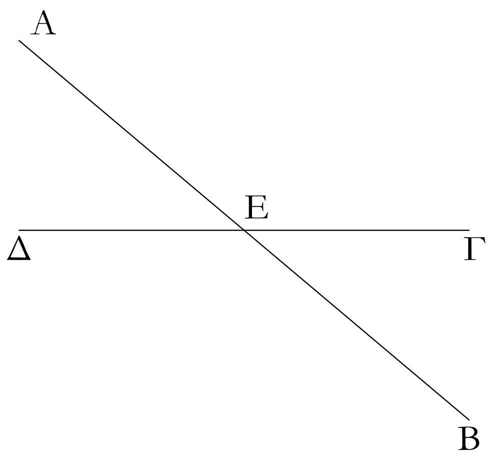
Ἐπεὶ γὰρ εὐθεῖα ἡ ΑΕ ἐπ᾿ εὐθεῖαν τὴν ΓΔ ἐφέστηκε γωνίας ποιοῦσα τὰς ὑπὸ ΓΕΑ, ΑΕΔ, αἱ ἄρα ὑπὸ ΓΕΑ, ΑΕΔ γωνίαι δυσὶν ὀρθαῖς ἴσαι εἰσίν. πάλιν, ἐπεὶ εὐθεῖα

Proposition 15

If two straight-lines cut one another then they make the vertically opposite angles equal to one another.

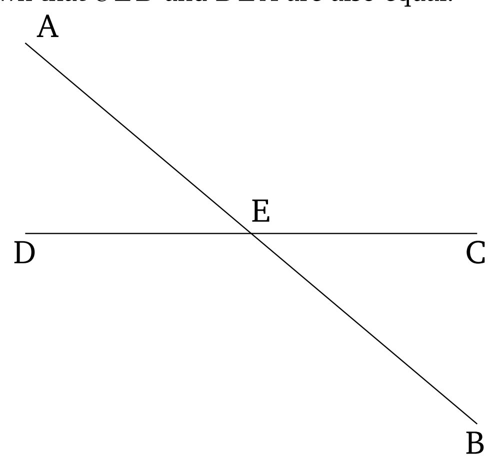
For let the two straight-lines AB and CD cut one another at the point E. I say that angle AEC is equal to (angle) DEB, and (angle) CEB to (angle) AED.

For since the straight-line AE stands on the straight-line CD, making the angles CEA and AED, the (sum of the) angles CEA and AED is thus equal to two rightἡ ΔΕ ἐπ᾿ εὐθεῖαν τὴν ΑΒ ἐφέστηκε γωνίας ποιοῦσα τὰς ὑπὸ ΑΕΔ, ΔΕΒ, αἱ ἄρα ὑπὸ ΑΕΔ, ΔΕΒ γωνίαι δυσὶν ὀρθαῖς ἴσαι εἰσίν. ἐδείχθησαν δὲ καὶ αἱ ὑπὸ ΓΕΑ, ΑΕΔ δυσὶν ὀρθαῖς ἴσαι· ἁι ἄρα ὑπὸ ΓΕΑ, ΑΕΔ ταῖς ὑπὸ ΑΕΔ, ΔΕΒ ἴσαι εἰσίν. κοινὴ ἀφῃρήσθω ἡ ὑπὸ ΑΕΔ· λοιπὴ ἄρα ἡ ὑπὸ ΓΕΑ λοιπῇ τῇ ὑπὸ ΒΕΔ ἴση ἐστίν· ὁμοίως δὴ δειχθήσεται, ὅτι καὶ αἱ ὑπὸ ΓΕΒ, ΔΕΑ ἴσαι εἰσίν.



Ἐὰν ἄρα δύο εὐθεῖαι τέμνωσιν ἀλλήλας, τὰς κατὰ κορυφὴν γωνίας ἴσας ἀλλήλαις ποιοῦσιν· ὅπερ ἔδει δεῖξαι.

angles [Prop. 1.13]. Again, since the straight-line DE stands on the straight-line AB, making the angles AED and DEB, the (sum of the) angles AED and DEB is thus equal to two right-angles [Prop. 1.13]. But (the sum of) CEA and AED was also shown (to be) equal to two right-angles. Thus, (the sum of) CEA and AED is equal to (the sum of) AED and DEB [C.N. 1]. Let AED have been subtracted from both. Thus, the remainder CEA is equal to the remainder BED [C.N. 3]. Similarly, it can be shown that CEB and DEA are also equal.



Thus, if two straight-lines cut one another then they make the vertically opposite angles equal to one another. (Which is) the very thing it was required to show.

ιϛ΄.

Παντὸς τριγώνου μιᾶς τῶν πλευρῶν προσεκβληθείσης ἡ ἐκτὸς γωνία ἑκατέρας τῶν ἐντὸς καὶ ἀπεναντίον γωνιῶν μείζων ἐστίν.

Ἔστω τρίγωνον τὸ ΑΒΓ, καὶ προσεκβεβλήσθω αὐτοῦ μία πλευρὰ ἡ ΒΓ ἐπὶ τὸ Δ· λὲγω, ὅτι ἡ ἐκτὸς γωνία ἡ ὑπὸ ΑΓΔ μείζων ἐστὶν ἑκατέρας τῶν ἐντὸς καὶ ἀπεναντίον τῶν ὑπὸ ΓΒΑ, ΒΑΓ γωνιῶν.

Τετμήσθω ἡ ΑΓ δίχα κατὰ τὸ Ε, καὶ ἐπιζευχθεῖσα ἡ ΒΕ ἐκβεβλήσθω ἐπ᾿ εὐθείας ἐπὶ τὸ Ζ, καὶ κείσθω τῇ ΒΕ ἴση ἡ ΕΖ, καὶ ἐπεζεύχθω ἡ ΖΓ, καὶ διήχθω ἡ ΑΓ ἐπὶ τὸ Η.

Ἐπεὶ οὖν ἴση ἐστὶν ἡ μὲν ΑΕ τῇ ΕΓ, ἡ δὲ ΒΕ τῇ ΕΖ, δύο δὴ αἱ ΑΕ, ΕΒ δυσὶ ταῖς ΓΕ, ΕΖ ἴσαι εἰσὶν ἑκατέρα ἑκατέρᾳ· καὶ γωνία ἡ ὑπὸ ΑΕΒ γωνίᾳ τῇ ὑπὸ ΖΕΓ ἴση ἐστίν· κατὰ κορυφὴν γάρ· βάσις ἄρα ἡ ΑΒ βάσει τῇ ΖΓ ἴση ἐστίν, καὶ τὸ ΑΒΕ τρίγωνον τῷ ΖΕΓ τριγώνῳ ἐστὶν ἴσον, καὶ αἱ λοιπαὶ γωνίαι ταῖς λοιπαῖς γωνίαις ἴσαι εἰσὶν ἑκατέρα ἑκατέρᾳ, ὑφ᾿ ἃς αἱ ἴσας πλευραὶ ὑποτείνουσιν· ἴση ἄρα ἐστὶν ἡ ὑπὸ ΒΑΕ τῇ ὑπὸ ΕΓΖ. μείζων δέ ἐστιν ἡ ὑπὸ ΕΓΔ τῆς ὑπὸ ΕΓΖ· μείζων ἄρα ἡ ὑπὸ ΑΓΔ τῆς ὑπὸ ΒΑΕ. Ὁμοίως δὴ τῆς ΒΓ τετμημένης δίχα δειχθήσεται

Proposition 16

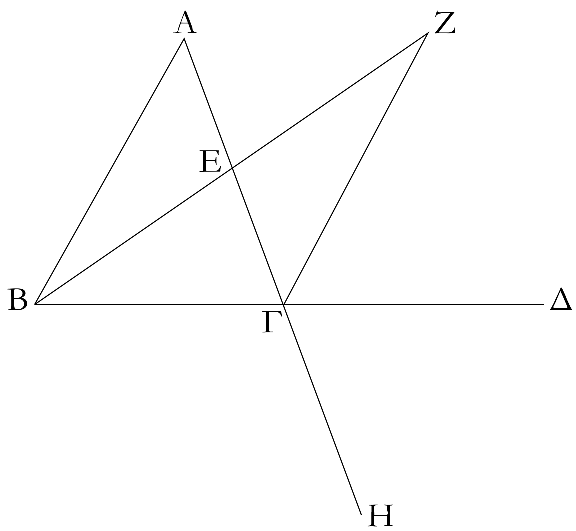
For any triangle, when one of the sides is produced, the external angle is greater than each of the internal and opposite angles.

Let ABC be a triangle, and let one of its sides BC have been produced to D. I say that the external angle ACD is greater than each of the internal and opposite angles, CBA and BAC.

Let the (straight-line) AC have been cut in half at (point) E [Prop. 1.10]. And BE being joined, let it have been produced in a straight-line to (point) F.† And let EF be made equal to BE [Prop. 1.3], and let FC have been joined, and let AC have been drawn through to (point) G.

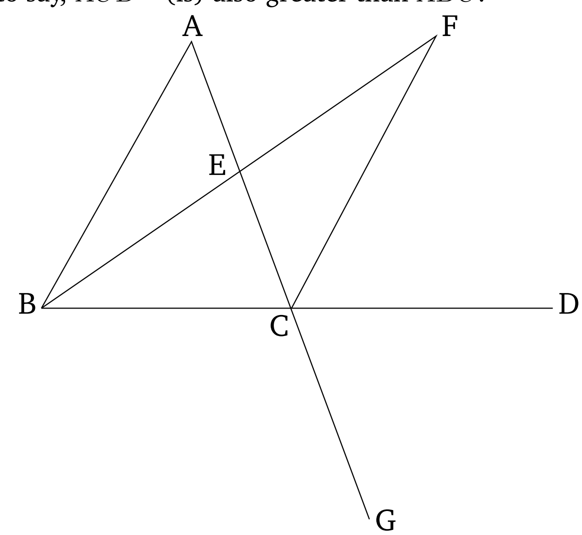
Therefore, since AE is equal to EC, and BE to EF, the two (straight-lines) AE, EB are equal to the two (straight-lines) CE, EF, respectively. Also, angle AEB is equal to angle FEC, for (they are) vertically opposite [Prop. 1.15]. Thus, the base AB is equal to the base FC, and the triangle ABE is equal to the triangle FEC, and the remaining angles subtended by the equal sides are equal to the corresponding remaining angles [Prop. 1.4].

καὶ ἡ ὑπὸ ΒΓΗ, τουτέστιν ἡ ὑπὸ ΑΓΔ, μείζων καὶ τῆς ὑπὸ ΑΒΓ.



Παντὸς ἄρα τριγώνου μιᾶς τῶν πλευρῶν προσεκβληθείσης ἡ ἐκτὸς γωνία ἑκατέρας τῶν ἐντὸς καὶ ἀπεναντίον γωνιῶν μείζων ἐστίν· ὅπερ ἔδει δεῖξαι.

Thus, BAE is equal to ECF. But ECD is greater than ECF. Thus, ACD is greater than BAE. Similarly, by having cut BC in half, it can be shown (that) BCG—that is to say, ACD—(is) also greater than ABC.

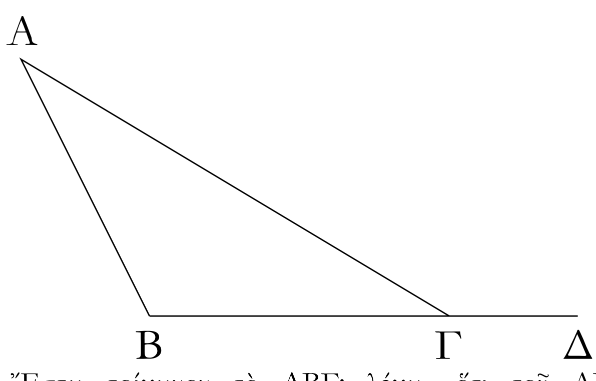


Thus, for any triangle, when one of the sides is produced, the external angle is greater than each of the internal and opposite angles. (Which is) the very thing it was required to show.

† The implicit assumption that the point F lies in the interior of the angle ABC should be counted as an additional postulate.

ιζ΄.

Παντὸς τριγώνου αἱ δύο γωνίαι δύο ὀρθῶν ἐλάσσονές εἰσι πάντῃ μεταλαμβανόμεναι.



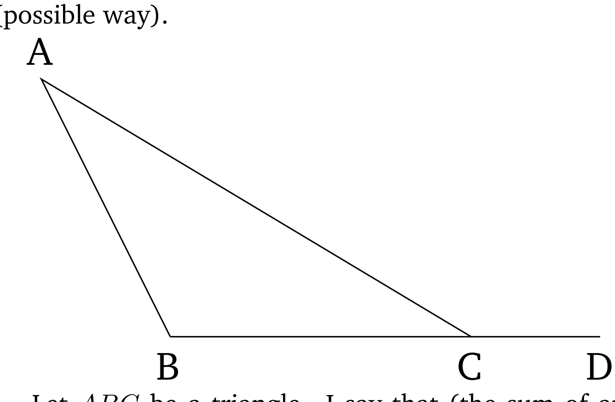
Ἔστω τρίγωνον τὸ ΑΒΓ· λέγω, ὅτι τοῦ ΑΒΓ τριγώνου αἱ δύο γωνίαι δύο ὀρθῶν ἐλάττονές εἰσι πάντῃ μεταλαμβανόμεναι.

Ἐκβεβλήσθω γὰρ ἡ ΒΓ ἐπὶ τὸ Δ.

Καὶ ἐπεὶ τριγώνου τοῦ ΑΒΓ ἐκτός ἐστι γωνία ἡ ὑπὸ ΑΓΔ, μείζων ἐστὶ τῆς ἐντὸς καὶ ἀπεναντίον τῆς ὑπὸ ΑΒΓ. κοινὴ προσκείσθω ἡ ὑπὸ ΑΓΒ· αἱ ἄρα ὑπὸ ΑΓΔ, ΑΓΒ τῶν ὑπὸ ΑΒΓ, ΒΓΑ μείζονές εἰσιν. ἀλλ᾽ αἱ ὑπὸ ΑΓΔ,

Proposition 17

For any triangle, (the sum of any) two angles is less than two right-angles, (the angles) being taken up in any (possible way).



Let ABC be a triangle. I say that (the sum of any) two angles of triangle ABC is less than two right-angles, (the angles) being taken up in any (possible way).

For let BC have been produced to D.

And since the angle ACD is external to triangle ABC, it is greater than the internal and opposite angle ABC [Prop. 1.16]. Let ACB have been added to both. Thus, the (sum of the angles) ACD and ACB is greater than

ΑΓΒ δύο ὀρθαῖς ἴσαι εἰσίν· αἱ ἄρα ὑπὸ ΑΒΓ, ΒΓΑ δύο ὀρθῶν ἐλάσσονές εἰσιν. ὁμοίως δὴ δείξομεν, ὅτι καὶ αἱ ὑπὸ ΒΑΓ, ΑΓΒ δύο ὀρθῶν ἐλάσσονές εἰσι καὶ ἔτι αἱ ὑπὸ ΓΑΒ, ΑΒΓ.

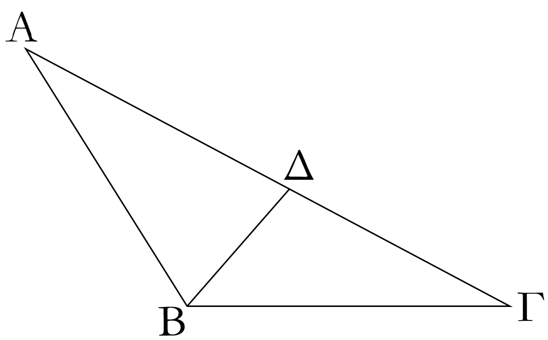
Παντὸς ἄρα τριγώνου αἱ δύο γωνίαι δύο ὀρθῶν ἐλάσσονές εἰσι πάντῃ μεταλαμβανόμεναι· ὅπερ ἔδει δεῖξαι.

the (sum of the angles) ABC and BCA. But, (the sum of) ACD and ACB is equal to two right-angles [Prop. 1.13]. Thus, (the sum of) ABC and BCA is less than two right-angles. Similarly, we can show that (the sum of) BAC and ACB is also less than two right-angles, and again (that the sum of) CAB and ABC (is less than two right-angles).

Thus, for any triangle, (the sum of any) two angles is less than two right-angles, (the angles) being taken up in any (possible way). (Which is) the very thing it was required to show.

ιη΄.

Παντὸς τριγώνου ἡ μείζων πλευρὰ τὴν μείζονα γωνίαν ὑποτείνει.



Ἔστω γὰρ τρίγωνον τὸ ΑΒΓ μείζονα ἔχον τὴν ΑΓ πλευρὰν τῆς ΑΒ· λέγω, ὅτι καὶ γωνία ἡ ὑπὸ ΑΒΓ μείζων ἐστὶ τῆς ὑπὸ ΒΓΑ·

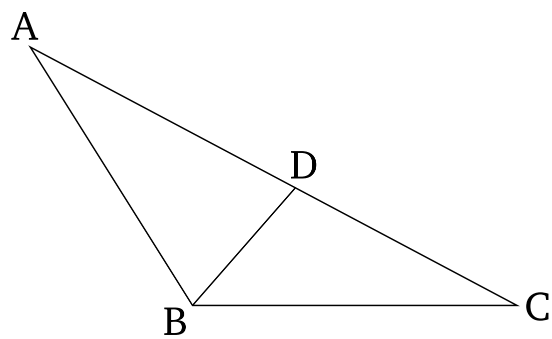
Ἐπεὶ γὰρ μείζων ἐστὶν ἡ ΑΓ τῆς ΑΒ, κείσθω τῇ ΑΒ ἴση ἡ ΑΔ, καὶ ἐπεζεύχθω ἡ ΒΔ.

Καὶ ἐπεὶ τριγώνου τοῦ ΒΓΔ ἐκτός ἐστι γωνία ἡ ὑπὸ ΑΔΒ, μείζων ἐστὶ τῆς ἐντὸς καὶ ἀπεναντίον τῆς ὑπὸ ΔΓΒ· ἴση δὲ ἡ ὑπὸ ΑΔΒ τῇ ὑπὸ ΑΒΔ, ἐπεὶ καὶ πλευρὰ ἡ ΑΒ τῇ ΑΔ ἐστιν ἴση· μείζων ἄρα καὶ ἡ ὑπὸ ΑΒΔ τῆς ὑπὸ ΑΓΒ· πολλῷ ἄρα ἡ ὑπὸ ΑΒΓ μείζων ἐστὶ τῆς ὑπὸ ΑΓΒ.

Παντὸς ἄρα τριγώνου ἡ μείζων πλευρὰ τὴν μείζονα γωνίαν ὑποτείνει· ὅπερ ἔδει δεῖξαι.

Proposition 18

For any triangle, the greater side subtends the greater angle.



For let ABC be a triangle having side AC greater than AB. I say that angle ABC is also greater than BCA.

For since AC is greater than AB, let AD be made equal to AB [Prop. 1.3], and let BD have been joined.

And since angle ADB is external to triangle BCD, it is greater than the internal and opposite (angle) DCB [Prop. 1.16]. But ADB (is) equal to ABD, since side AB is also equal to side AD [Prop. 1.5]. Thus, ABD is also greater than ACB. Thus, ABC is much greater than ACB.

Thus, for any triangle, the greater side subtends the greater angle. (Which is) the very thing it was required to show.

ιθ΄.

Παντὸς τριγώνου ὑπὸ τὴν μείζονα γωνίαν ἡ μείζων πλευρὰ ὑποτείνει.

Ἔστω τρίγωνον τὸ ΑΒΓ μείζονα ἔχον τὴν ὑπὸ ΑΒΓ γωνίαν τῆς ὑπὸ ΒΓΑ· λέγω, ὅτι καὶ πλευρὰ ἡ ΑΓ πλευρᾶς τῆς ΑΒ μείζων ἐστίν.

Εἰ γὰρ μή, ἤτοι ἴση ἐστὶν ἡ ΑΓ τῇ ΑΒ ἢ ἐλάσσων· ἴση μὲν οὖν οὐκ ἔστιν ἡ ΑΓ τῇ ΑΒ· ἴση γὰρ ἂν ἦν καὶ γωνία ἡ ὑπὸ ΑΒΓ τῇ ὑπὸ ΑΓΒ· οὐκ ἔστι δέ· οὐκ ἄρα ἴση ἐστὶν ἡ ΑΓ τῇ ΑΒ. οὐδὲ μὴν ἐλάσσων ἐστὶν ἡ ΑΓ

Proposition 19

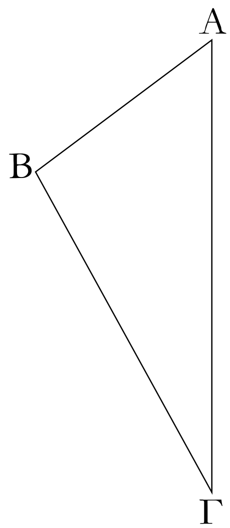
For any triangle, the greater angle is subtended by the greater side.

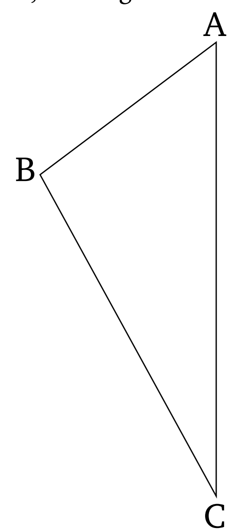
Let ABC be a triangle having the angle ABC greater than BCA. I say that side AC is also greater than side AB.

For if not, AC is certainly either equal to, or less than, AB. In fact, AC is not equal to AB. For then angle ABC would also have been equal to ACB [Prop. 1.5]. But it is not. Thus, AC is not equal to AB. Neither, indeed, is AC

τῆς ΑΒ· ἐλάσσων γὰρ ἂν ἦν καὶ γωνία ἡ ὑπὸ ΑΒΓ τῆς ὑπὸ ΑΓΒ· οὐκ ἔστι δέ· οὐκ ἄρα ἐλάσσων ἐστὶν ἡ ΑΓ τῆς ΑΒ. ἐδείχθη δέ, ὅτι οὐδὲ ἴση ἐστίν. μείζων ἄρα ἐστὶν ἡ ΑΓ τῆς ΑΒ.

less than AB. For then angle ABC would also have been less than ACB [Prop. 1.18]. But it is not. Thus, AC is not less than AB. But it was shown that (AC) is also not equal (to AB). Thus, AC is greater than AB.





Παντὸς ἄρα τριγώνου ὑπὸ τὴν μείζονα γωνίαν ἡ μείζων πλευρὰ ὑποτείνει· ὅπερ ἔδει δεῖξαι.

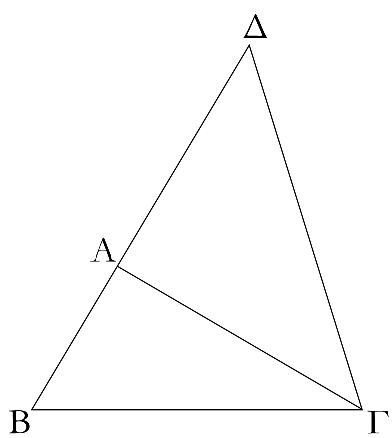
Thus, for any triangle, the greater angle is subtended by the greater side. (Which is) the very thing it was required to show.

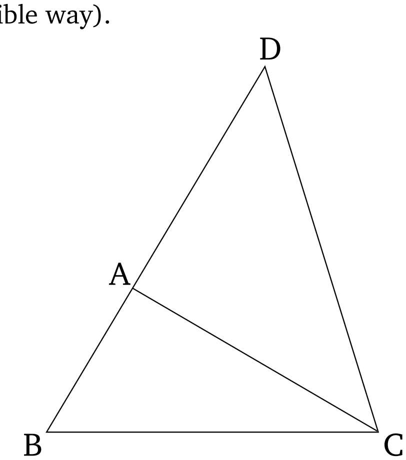
κ´.

Proposition 20

Παντὸς τριγώνου αἱ δύο πλευραὶ τῆς λοιπῆς μείζονές εἰσι πάντη μεταλαμβανόμεναι.

For any triangle, (the sum of any) two sides is greater than the remaining (side), (the sides) being taken up in any (possible way).





Ἔστω γὰρ τρίγωνον τὸ ΑΒΓ· λέγω, ὅτι τοῦ ΑΒΓ τριγώνου αἱ δύο πλευραὶ τῆς λοιπῆς μείζονές εἰσι παντη μεταλαμβανόμεναι, αἱ μὲν ΒΑ, ΑΓ τῆς ΒΓ, αἱ δὲ ΑΒ, ΒΓ τῆς ΑΓ, αἱ δὲ ΒΓ, ΓΑ τῆς ΑΒ.

Διήχθω γὰρ ἡ ΒΑ ἐπὶ τὸ Δ σημεῖον, καὶ κείσθω τῇ ΓΑ ἴση ἡ ΑΔ, καὶ ἐπεζεύχθω ἡ ΔΓ.

Ἐπεὶ οὖν ἴση ἐστὶν ἡ ΔΑ τῇ ΑΓ, ἴση ἐστὶ καὶ γωνία ἡ ὑπὸ ΑΔΓ τῇ ὑπὸ ΑΓΔ· μείζων ἄρα ἡ ὑπὸ ΒΓΔ τῆς

For let ABC be a triangle. I say that for triangle ABC (the sum of any) two sides is greater than the remaining (side), (the sides) being taken up in any (possible way). (So), (the sum of) BA and AC (is greater) than BC, (the sum of) AB and BC than AC, and (the sum of) BC and CA than AB.

For let BA have been drawn through to point D, and let AD be made equal to CA [Prop. 1.3], and let DC

ὑπὸ ΑΔΓ· καὶ ἐπεὶ τρίγωνόν ἐστι τὸ ΔΓΒ μείζονα ἔχον τὴν ὑπὸ ΒΓΔ γωνίαν τῆς ὑπὸ ΒΔΓ, ὑπὸ δὲ τὴν μείζονα γωνίαν ἡ μείζων πλευρὰ ὑποτείνει, ἡ ΔΒ ἄρα τῆς ΒΓ ἐστι μείζων. ἴση δὲ ἡ ΔΑ τῇ ΑΓ· μείζονες ἄρα αἱ ΒΑ, ΑΓ τῆς ΒΓ· ὁμοίως δὴ δείξομεν, ὅτι καὶ αἱ μὲν ΑΒ, ΒΓ τῆς ΓΑ μείζονές εἰσιν, αἱ δὲ ΒΓ, ΓΑ τῆς ΑΒ.

Παντὸς ἄρα τριγώνου αἱ δύο πλευραὶ τῆς λοιπῆς μείζονές εἰσι πάντῃ μεταλαμβανόμεναι· ὅπερ ἔδει δεῖξαι.

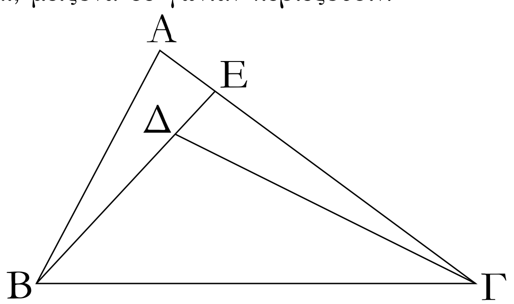
have been joined.

Therefore, since DA is equal to AC, the angle ADC is also equal to ACD [Prop. 1.5]. Thus, BCD is greater than ADC. And since triangle DCB has the angle BCD greater than BDC, and the greater angle subtends the greater side [Prop. 1.19], DB is thus greater than BC. But DA is equal to AC. Thus, (the sum of) BA and AC is greater than BC. Similarly, we can show that (the sum of) AB and BC is also greater than CA, and (the sum of) BC and CA than AB.

Thus, for any triangle, (the sum of any) two sides is greater than the remaining (side), (the sides) being taken up in any (possible way). (Which is) the very thing it was required to show.

κα΄.

Ἐὰν τριγώνου ἐπὶ μιᾶς τῶν πλευρῶν ἀπὸ τῶν περάτων δύο εὐθεῖαι ἐντὸς συσταθῶσιν, αἱ συσταθεῖσαι τῶν λοιπῶν τοῦ τριγώνου δύο πλευρῶν ἐλάττονες μὲν ἔσονται, μείζονα δὲ γωνίαν περιέξουσιν.



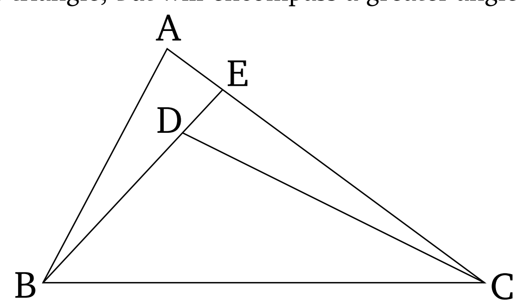
Τριγώνου γὰρ τοῦ ΑΒΓ ἐπὶ μιᾶς τῶν πλευρῶν τῆς ΒΓ ἀπὸ τῶν περάτων τῶν Β, Γ δύο εὐθεῖαι ἐντὸς συνεστάτωσαν αἱ ΒΔ, ΔΓ· λέγω, ὅτι αἱ ΒΔ, ΔΓ τῶν λοιπῶν τοῦ τριγώνου δύο πλευρῶν τῶν ΒΑ, ΑΓ ἐλάσσονες μέν εἰσιν, μείζονα δὲ γωνίαν περιέχουσι τὴν ὑπὸ ΒΔΓ τῆς ὑπὸ ΒΑΓ.

Διήχθω γὰρ ἡ ΒΔ ἐπὶ τὸ Ε. καὶ ἐπεὶ παντὸς τριγώνου αἱ δύο πλευραὶ τῆς λοιπῆς μείζονές εἰσιν, τοῦ ΑΒΕ ἄρα τριγώνου αἱ δύο πλευραὶ αἱ ΑΒ, ΑΕ τῆς ΒΕ μείζονές εἰσιν· κοινὴ προσκείσθω ἡ ΕΓ· αἱ ἄρα ΒΑ, ΑΓ τῶν ΒΕ, ΕΓ μείζονές εἰσιν. πάλιν, ἐπεὶ τοῦ ΓΕΔ τριγώνου αἱ δύο πλευραὶ αἱ ΓΕ, ΕΔ τῆς ΓΔ μείζονές εἰσιν, κοινὴ προσκείσθω ἡ ΔΒ· αἱ ΓΕ, ΕΒ ἄρα τῶν ΓΔ, ΔΒ μείζονές εἰσιν. ἀλλὰ τῶν ΒΕ, ΕΓ μείζονες ἐδείχθησαν αἱ ΒΑ, ΑΓ· πολλῷ ἄρα αἱ ΒΑ, ΑΓ τῶν ΒΔ, ΔΓ μείζονές εἰσιν.

Πάλιν, ἐπεὶ παντὸς τριγώνου ἡ ἐκτὸς γωνία τῆς ἐντὸς καὶ ἀπεναντίον μείζων ἐστίν, τοῦ ΓΔΕ ἄρα τριγώνου ἡ ἐκτὸς γωνία ἡ ὑπὸ ΒΔΓ μείζων ἐστὶ τῆς ὑπὸ ΓΕΔ. διὰ ταὐτὰ τοίνυν καὶ τοῦ ΑΒΕ τριγώνου ἡ ἐκτὸς γωνία ἡ ὑπὸ ΓΕΒ μείζων ἐστὶ τῆς ὑπὸ ΒΑΓ. ἀλλὰ τῆς ὑπὸ ΓΕΒ μείζων ἐδείχθη ἡ ὑπὸ ΒΔΓ· πολλῷ ἄρα ἡ ὑπὸ ΒΔΓ

Proposition 21

If two internal straight-lines are constructed on one of the sides of a triangle, from its ends, the constructed (straight-lines) will be less than the two remaining sides of the triangle, but will encompass a greater angle.



For let the two internal straight-lines BD and DC have been constructed on one of the sides BC of the triangle ABC, from its ends B and C (respectively). I say that BD and DC are less than the (sum of the) two remaining sides of the triangle BA and AC, but encompass an angle BDC greater than BAC.

For let BD have been drawn through to E. And since for every triangle (the sum of any) two sides is greater than the remaining (side) [Prop. 1.20], for triangle ABE the (sum of the) two sides AB and AE is thus greater than BE. Let EC have been added to both. Thus, (the sum of) BA and AC is greater than (the sum of) BE and EC. Again, since in triangle CED the (sum of the) two sides CE and ED is greater than CD, let DB have been added to both. Thus, (the sum of) CE and EB is greater than (the sum of) CD and DB. But, (the sum of) BA and AC was shown (to be) greater than (the sum of) BE and EC. Thus, (the sum of) BA and AC is much greater than (the sum of) BD and DC.

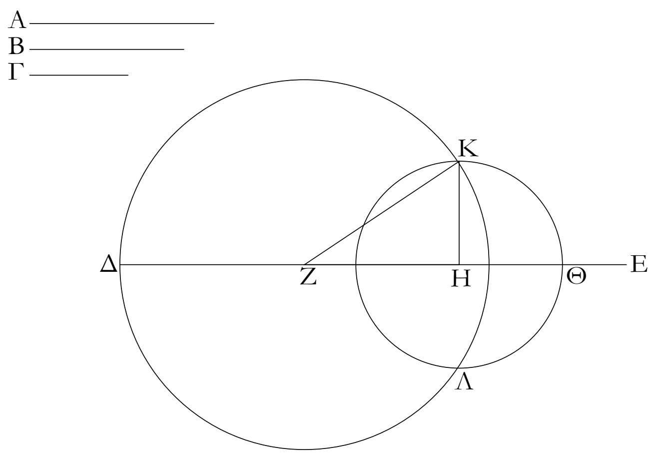
Again, since for every triangle the external angle is greater than the internal and opposite (angles) [Prop.

μείζων ἐστὶ τῆς ὑπὸ ΒΑΓ.

Ἐὰν ἄρα τριγώνου ἐπὶ μιᾶς τῶν πλευρῶν ἀπὸ τῶν περάτων δύο εὐθεῖαι ἐντὸς συσταθῶσιν, αἱ συσταθεῖσαι τῶν λοιπῶν τοῦ τριγώνου δύο πλευρῶν ἐλάττονες μέν εἰσιν, μείζονα δὲ γωνίαν περιέχουσιν· ὅπερ ἔδει δεῖξαι.

κβ΄.

Ἐκ τριῶν εὐθειῶν, αἵ εἰσιν ἴσαι τρισὶ ταῖς δοθείσαις [εὐθείαις], τρίγωνον συστήσασθαι· δεῖ δὲ τὰς δύο τῆς λοιπῆς μείζονας εἶναι πάντῃ μεταλαμβανομένας [διὰ τὸ καὶ παντὸς τριγώνου τὰς δύο πλευρὰς τῆς λοιπῆς μείζονας εἶναι πάντῃ μεταλαμβανομένας].



Ἔστωσαν αἱ δοθεῖσαι τρεῖς εὐθεῖαι αἱ Α, Β, Γ, ὧν αἱ δύο τῆς λοιπῆς μείζονες ἔστωσαν πάντῃ μεταλαμβανόμεναι, αἱ μὲν Α, Β τῆς Γ, αἱ δὲ Α, Γ τῆς Β, καὶ ἔτι αἱ Β, Γ τῆς Α· δεῖ δὴ ἐκ τῶν ἴσων ταῖς Α, Β, Γ τρίγωνον συστήσασθαι.

Ἐκκείσθω τις εὐθεῖα ἡ ΔΕ πεπερασμένη μὲν κατὰ τὸ Δ ἄπειρος δὲ κατὰ τὸ Ε, καὶ κείσθω τῇ μὲν Α ἴση ἡ ΔΖ, τῇ δὲ Β ἴση ἡ ΖΗ, τῇ δὲ Γ ἴση ἡ ΗΘ· καὶ κέντρῳ μὲν τῷ Ζ, διαστήματι δὲ τῷ ΖΔ κύκλος γεγράφθω ὁ ΔΚΛ· πάλιν κέντρῳ μὲν τῷ Η, διαστήματι δὲ τῷ ΗΘ κύκλος γεγράφθω ὁ ΚΛΘ, καὶ ἐπεζεύχθωσαν αἱ ΚΖ, ΚΗ· λέγω, ὅτι ἐκ τριῶν εὐθειῶν τῶν ἴσων ταῖς Α, Β, Γ τρίγωνον συνέσταται τὸ ΚΖΗ.

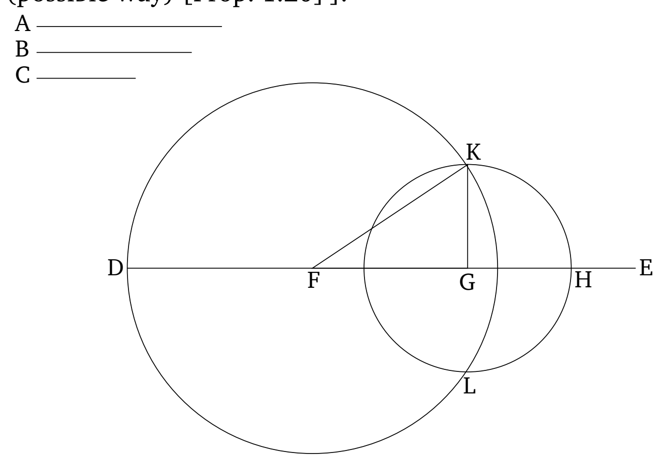
Ἐπεὶ γὰρ τὸ Ζ σημεῖον κέντρον ἐστὶ τοῦ ΔΚΛ κύκλου, ἴση ἐστὶν ἡ ΖΔ τῇ ΖΚ· ἀλλὰ ἡ ΖΔ τῇ Α ἐστιν ἴση. καὶ ἡ ΚΖ ἄρα τῇ Α ἐστιν ἴση. πάλιν, ἐπεὶ τὸ Η

1.16], for triangle CDE the external angle BDC is thus greater than CED. Accordingly, for the same (reason), the external angle CEB of the triangle ABE is also greater than BAC. But, BDC was shown (to be) greater than CEB. Thus, BDC is much greater than BAC.

Thus, if two internal straight-lines are constructed on one of the sides of a triangle, from its ends, the constructed (straight-lines) are less than the two remaining sides of the triangle, but encompass a greater angle. (Which is) the very thing it was required to show.

Proposition 22

To construct a triangle from three straight-lines which are equal to three given [straight-lines]. It is necessary for (the sum of) two (of the straight-lines) to be greater than the remaining (one), (the straight-lines) being taken up in any (possible way) [on account of the (fact that) for every triangle (the sum of any) two sides is greater than the remaining (one), (the sides) being taken up in any (possible way) [Prop. 1.20]].



Let A, B, and C be the three given straight-lines, of which let (the sum of any) two be greater than the remaining (one), (the straight-lines) being taken up in (any possible way). (Thus), (the sum of) A and B (is greater) than C, (the sum of) A and C than B, and also (the sum of) B and C than A. So it is required to construct a triangle from (straight-lines) equal to A, B, and C.

Let some straight-line DE be set out, terminated at D, and infinite in the direction of E. And let DF made equal to A [Prop. 1.3], and FG equal to B [Prop. 1.3], and GH equal to C [Prop. 1.3]. And let the circle DKL have been drawn with center F and radius FD. Again, let the circle KLH have been drawn with center G and radius GH. And let KF and KG have been joined. I say that the triangle KFG has been constructed from three straight-lines equal to A, B, and C.

σημεῖον κέντρον ἐστὶ τοῦ ΛΚΘ κύκλου, ἴση ἐστὶν ἡ ΗΘ τῇ ΗΚ· ἀλλὰ ἡ ΗΘ τῇ Γ ἐστιν ἴση· καὶ ἡ ΚΗ ἄρα τῇ Γ ἐστιν ἴση. ἐστὶ δὲ καὶ ἡ ΖΗ τῇ Β ἴση· αἱ τρεῖς ἄρα εὐθεῖαι αἱ ΚΖ, ΖΗ, ΗΚ τρισὶ ταῖς Α, Β, Γ ἴσαι εἰσίν.

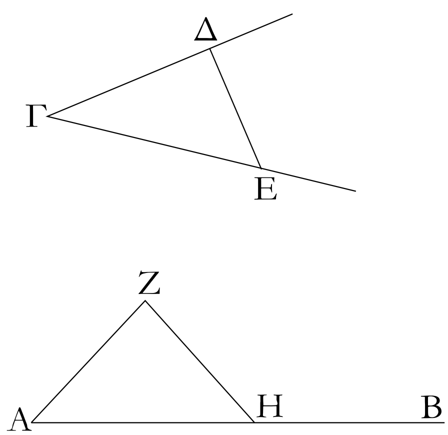
Ἐκ τριῶν ἄρα εὐθειῶν τῶν ΚΖ, ΖΗ, ΗΚ, αἵ εἰσιν ἴσαι τρισὶ ταῖς δοθείσαις εὐθείαις ταῖς Α, Β, Γ, τρίγωνον συνέσταται τὸ ΚΖΗ· ὅπερ ἔδει ποιῆσαι.

For since point F is the center of the circle DKL, FD is equal to FK. But, FD is equal to A. Thus, KF is also equal to A. Again, since point G is the center of the circle LKH, GH is equal to GK. But, GH is equal to C. Thus, KG is also equal to C. And FG is equal to B. Thus, the three straight-lines KF, FG, and GK are equal to A, B, and C (respectively).

Thus, the triangle KFG has been constructed from the three straight-lines KF, FG, and GK, which are equal to the three given straight-lines A, B, and C (respectively). (Which is) the very thing it was required to do.

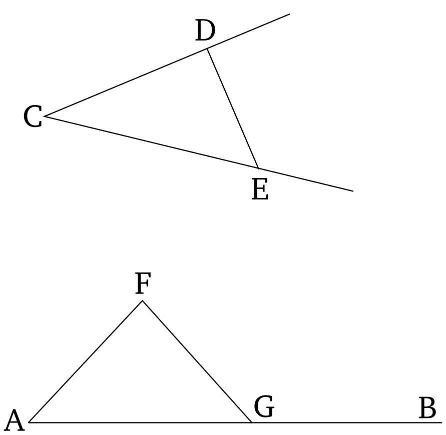
κγ´.

Πρὸς τῇ δοθείσῃ εὐθείᾳ καὶ τῷ πρὸς αὐτῇ σημείῳ τῇ δοθείσῃ γωνίᾳ εὐθυγράμμῳ ἴσην γωνίαν εὐθύγραμμον συστήσασθαι.



Proposition 23

To construct a rectilinear angle equal to a given rectilinear angle at a (given) point on a given straight-line.



Ἔστω ἡ μὲν δοθεῖσα εὐθεῖα ἡ ΑΒ, τὸ δὲ πρὸς αὐτῇ σημεῖον τὸ Α, ἡ δὲ δοθεῖσα γωνία εὐθύγραμμος ἡ ὑπὸ ΔΓΕ· δεῖ δὴ πρὸς τῇ δοθείσῃ εὐθείᾳ τῇ ΑΒ καὶ τῷ πρὸς αὐτῇ σημείῳ τῷ Α τῇ δοθείσῃ γωνίᾳ εὐθυγράμμῳ τῇ ὑπὸ ΔΓΕ ἴσην γωνίαν εὐθύγραμμον συστήσασθαι.

Εἰλήφθω ἐφ᾽ ἑκατέρας τῶν ΓΔ, ΓΕ τυχόντα σημεῖα τὰ Δ, Ε, καὶ ἐπεζεύχθω ἡ ΔΕ· καὶ ἐκ τριῶν εὐθειῶν, αἵ εἰσιν ἴσαι τρισὶ ταῖς ΓΔ, ΔΕ, ΓΕ, τρίγωνον συνεστάτω τὸ ΑΖΗ, ὥστε ἴσην εἶναι τὴν μὲν ΓΔ τῇ ΑΖ, τὴν δὲ ΓΕ τῇ ΑΗ, καὶ ἔτι τὴν ΔΕ τῇ ΖΗ.

Ἐπεὶ οὖν δύο αἱ ΔΓ, ΓΕ δύο ταῖς ΖΑ, ΑΗ ἴσαι εἰσὶν ἑκατέρα ἑκατέρᾳ, καὶ βάσις ἡ ΔΕ βάσει τῇ ΖΗ ἴση, γωνία ἄρα ἡ ὑπὸ ΔΓΕ γωνίᾳ τῇ ὑπὸ ΖΑΗ ἐστιν ἴση.

Πρὸς ἄρα τῇ δοθείσῃ εὐθείᾳ τῇ ΑΒ καὶ τῷ πρὸς αὐτῇ σημείῳ τῷ Α τῇ δοθείσῃ γωνίᾳ εὐθυγράμμῳ τῇ ὑπὸ ΔΓΕ ἴση γωνία εὐθύγραμμος συνέσταται ἡ ὑπὸ ΖΑΗ· ὅπερ ἔδει ποιῆσαι.

Let AB be the given straight-line, A the (given) point on it, and DCE the given rectilinear angle. So it is required to construct a rectilinear angle equal to the given rectilinear angle DCE at the (given) point A on the given straight-line AB.

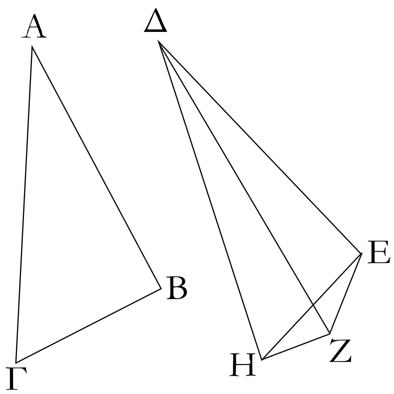
Let the points D and E have been taken somewhere on each of the (straight-lines) CD and CE (respectively), and let DE have been joined. And let the triangle AFG have been constructed from three straight-lines which are equal to CD, DE, and CE, such that CD is equal to AF, CE to AG, and also DE to FG [Prop. 1.22].

Therefore, since the two (straight-lines) DC, CE are equal to the two straight-lines FA, AG, respectively, and the base DE is equal to the base FG, the angle DCE is thus equal to the angle FAG [Prop. 1.8].

Thus, the rectilinear angle FAG, equal to the given rectilinear angle DCE, has been constructed at the (given) point A on the given straight-line AB. (Which is) the very thing it was required to do.

κδ΄.

Ἐὰν δύο τρίγωνα τὰς δύο πλευρὰς [ταῖς] δύο πλευραῖς ἴσας ἔχῃ ἑκατέραν ἑκατέρᾳ, τὴν δὲ γωνίαν τῆς γωνίας μείζονα ἔχῃ τὴν ὑπὸ τῶν ἴσων εὐθειῶν περιεχομένην, καὶ τὴν βάσιν τῆς βάσεως μείζονα ἕξει.



Ἔστω δύο τρίγωνα τὰ ΑΒΓ, ΔΕΖ τὰς δύο πλευρὰς τὰς ΑΒ, ΑΓ ταῖς δύο πλευραῖς ταῖς ΔΕ, ΔΖ ἴσας ἔχοντα ἑκατέραν ἑκατέρᾳ, τὴν μὲν ΑΒ τῇ ΔΕ τὴν δὲ ΑΓ τῇ ΔΖ, ἡ δὲ πρὸς τῷ Α γωνία τῆς πρὸς τῷ Δ γωνίας μείζων ἔστω· λέγω, ὅτι καὶ βάσις ἡ ΒΓ βάσεως τῆς ΕΖ μείζων ἐστίν.

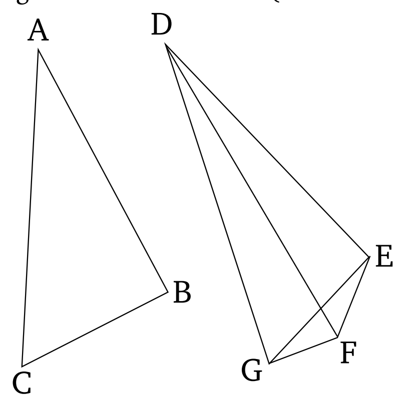
Ἐπεὶ γὰρ μείζων ἡ ὑπὸ ΒΑΓ γωνία τῆς ὑπὸ ΕΔΖ γωνίας, συνεστάτω πρὸς τῇ ΔΕ εὐθείᾳ καὶ τῷ πρὸς αὐτῇ σημείῳ τῷ Δ τῇ ὑπὸ ΒΑΓ γωνίᾳ ἴση ἡ ὑπὸ ΕΔΗ, καὶ κείσθω ὁποτέρᾳ τῶν ΑΓ, ΔΖ ἴση ἡ ΔΗ, καὶ ἐπεζεύχθωσαν αἱ ΕΗ, ΖΗ.

Ἐπεὶ οὖν ἴση ἐστὶν ἡ μὲν ΑΒ τῇ ΔΕ, ἡ δὲ ΑΓ τῇ ΔΗ, δύο δὴ αἱ ΒΑ, ΑΓ δυσὶ ταῖς ΕΔ, ΔΗ ἴσαι εἰσὶν ἑκατέρα ἑκατέρᾳ· καὶ γωνία ἡ ὑπὸ ΒΑΓ γωνίᾳ τῇ ὑπὸ ΕΔΗ ἴση· βάσις ἄρα ἡ ΒΓ βάσει τῇ ΕΗ ἐστιν ἴση. πάλιν, ἐπεὶ ἴση ἐστὶν ἡ ΔΖ τῇ ΔΗ, ἴση ἐστὶ καὶ ἡ ὑπὸ ΔΗΖ γωνία τῇ ὑπὸ ΔΖΗ· μείζων ἄρα ἡ ὑπὸ ΔΖΗ τῆς ὑπὸ ΕΗΖ· πολλῷ ἄρα μείζων ἐστὶν ἡ ὑπὸ ΕΖΗ τῆς ὑπὸ ΕΗΖ. καὶ ἐπεὶ τρίγωνόν ἐστι τὸ ΕΖΗ μείζονα ἔχον τὴν ὑπὸ ΕΖΗ γωνίαν τῆς ὑπὸ ΕΗΖ, ὑπὸ δὲ τὴν μείζονα γωνίαν ἡ μείζων πλευρὰ ὑποτείνει, μείζων ἄρα καὶ πλευρὰ ἡ ΕΗ τῆς ΕΖ. ἴση δὲ ἡ ΕΗ τῇ ΒΓ· μείζων ἄρα καὶ ἡ ΒΓ τῆς ΕΖ.

Ἐὰν ἄρα δύο τρίγωνα τὰς δύο πλευρὰς δυσὶ πλευραῖς ἴσας ἔχῃ ἑκατέραν ἑκατέρᾳ, τὴν δὲ γωνίαν τῆς γωνίας μείζονα ἔχῃ τὴν ὑπὸ τῶν ἴσων εὐθειῶν περιεχομένην, καὶ τὴν βάσιν τῆς βάσεως μείζονα ἕξει· ὅπερ ἔδει δεῖξαι.

Proposition 24

If two triangles have two sides equal to two sides, respectively, but (one) has the angle encompassed by the equal straight-lines greater than the (corresponding) angle (in the other), then (the former triangle) will also have a base greater than the base (of the latter).



Let ABC and DEF be two triangles having the two sides AB and AC equal to the two sides DE and DF, respectively. (That is), AB to DE, and AC to DF. Let them also have the angle at A greater than the angle at D. I say that the base BC is greater than the base EF.

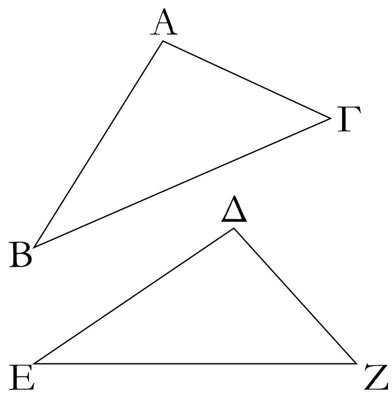
For since angle BAC is greater than angle EDF, let (angle) EDG, equal to angle BAC, have been constructed at point D on the straight-line DE [Prop. 1.23]. And let DG be made equal to either of AC or DF [Prop. 1.3], and let EG and FG have been joined.

Therefore, since AB is equal to DE and AC to DG, the two (straight-lines) BA, AC are equal to the two (straight-lines) ED, DG, respectively. Also the angle BAC is equal to the angle EDG. Thus, the base BC is equal to the base EG [Prop. 1.4]. Again, since DF is equal to DG, angle DGF is also equal to angle DFG [Prop. 1.5]. Thus, DFG (is) greater than EGF. Thus, EFG is much greater than EGF. And since triangle EFG has angle EFG greater than EGF, and the greater angle subtends the greater side [Prop. 1.19], side EG (is) thus also greater than EF. But EG (is) equal to BC. Thus, BC (is) also greater than EF.

Thus, if two triangles have two sides equal to two sides, respectively, but (one) has the angle encompassed by the equal straight-lines greater than the (corresponding) angle (in the other), then (the former triangle) will also have a base greater than the base (of the latter). (Which is) the very thing it was required to show.

κε΄.

Ἐὰν δύο τρίγωνα τὰς δύο πλευρὰς δυσὶ πλευραῖς ἴσας ἔχῃ ἑκατέραν ἑκατέρᾳ, τὴν δὲ βασίν τῆς βάσεως μείζονα ἔχῃ, καὶ τὴν γωνίαν τῆς γωνίας μείζονα ἕξει τὴν ὑπὸ τῶν ἴσων εὐθειῶν περιεχομένην.



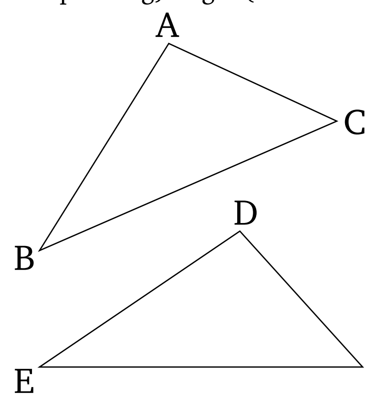
Ἔστω δύο τρίγωνα τὰ ΑΒΓ, ΔΕΖ τὰς δύο πλευρὰς τὰς ΑΒ, ΑΓ ταῖς δύο πλευραῖς ταῖς ΔΕ, ΔΖ ἴσας ἔχοντα ἑκατέραν ἑκατέρᾳ, τὴν μὲν ΑΒ τῇ ΔΕ, τὴν δὲ ΑΓ τῇ ΔΖ· βάσις δὲ ἡ ΒΓ βάσεως τῆς ΕΖ μείζων ἔστω· λέγω, ὅτι καὶ γωνία ἡ ὑπὸ ΒΑΓ γωνίας τῆς ὑπὸ ΕΔΖ μείζων ἐστίν.

Εἰ γὰρ μή, ἤτοι ἴση ἐστὶν αὐτῇ ἢ ἐλάσσων· ἴση μὲν οὖν οὐκ ἔστιν ἡ ὑπὸ ΒΑΓ τῇ ὑπὸ ΕΔΖ· ἴση γὰρ ἂν ἦν καὶ βάσις ἡ ΒΓ βάσει τῇ ΕΖ· οὐκ ἔστι δέ. οὐκ ἄρα ἴση ἐστὶ γωνία ἡ ὑπὸ ΒΑΓ τῇ ὑπὸ ΕΔΖ· οὐδὲ μὴν ἐλάσσων ἐστὶν ἡ ὑπὸ ΒΑΓ τῆς ὑπὸ ΕΔΖ· ἐλάσσων γὰρ ἂν ἦν καὶ βάσις ἡ ΒΓ βάσεως τῆς ΕΖ· οὐκ ἔστι δέ· οὐκ ἄρα ἐλάσσων ἐστὶν ἡ ὑπὸ ΒΑΓ γωνία τῆς ὑπὸ ΕΔΖ. ἐδείχθη δέ, ὅτι οὐδὲ ἴση· μείζων ἄρα ἐστὶν ἡ ὑπὸ ΒΑΓ τῆς ὑπὸ ΕΔΖ.

Ἐὰν ἄρα δύο τρίγωνα τὰς δύο πλευρὰς δυσὶ πλευραῖς ἴσας ἔχῃ ἑκατέραν ἑκάτερᾳ, τὴν δὲ βασίν τῆς βάσεως μείζονα ἔχῃ, καὶ τὴν γωνίαν τῆς γωνίας μείζονα ἕξει τὴν ὑπὸ τῶν ἴσων εὐθειῶν περιεχομένην· ὅπερ ἔδει δεῖξαι.

Proposition 25

If two triangles have two sides equal to two sides, respectively, but (one) has a base greater than the base (of the other), then (the former triangle) will also have the angle encompassed by the equal straight-lines greater than the (corresponding) angle (in the latter).



Let ABC and DEF be two triangles having the two sides AB and AC equal to the two sides DE and DF, respectively (That is), AB to DE, and AC to DF. And let the base BC be greater than the base EF. I say that angle BAC is also greater than EDF.

For if not, (BAC) is certainly either equal to, or less than, (EDF). In fact, BAC is not equal to EDF. For then the base BC would also have been equal to EF [Prop. 1.4]. But it is not. Thus, angle BAC is not equal to EDF. Neither, indeed, is BAC less than EDF. For then the base BC would also have been less than EF [Prop. 1.24]. But it is not. Thus, angle BAC is not less than EDF. But it was shown that (BAC is) also not equal (to EDF). Thus, BAC is greater than EDF.

Thus, if two triangles have two sides equal to two sides, respectively, but (one) has a base greater than the base (of the other), then (the former triangle) will also have the angle encompassed by the equal straight-lines greater than the (corresponding) angle (in the latter). (Which is) the very thing it was required to show.

κϛ΄.

Ἐὰν δύο τρίγωνα τὰς δύο γωνίας δυσὶ γωνίαις ἴσας ἔχῃ ἑκαρέραν ἑκαρέρᾳ καὶ μίαν πλευρὰν μιᾷ πλευρᾷ ἴσην ἤτοι τὴν πρὸς ταῖς ἴσαις γωνίαις ἢ τὴν ὑποτείνουσαν ὑπὸ μίαν τῶν ἴσων γωνιῶν, καὶ τὰς λοιπὰς πλευρὰς ταῖς λοιπαῖς πλευραῖς ἴσας ἕξει [ἑκατέραν ἑκατέρᾳ] καὶ τὴν λοιπὴν γωνίαν τῇ λοιπῇ γωνίᾳ.

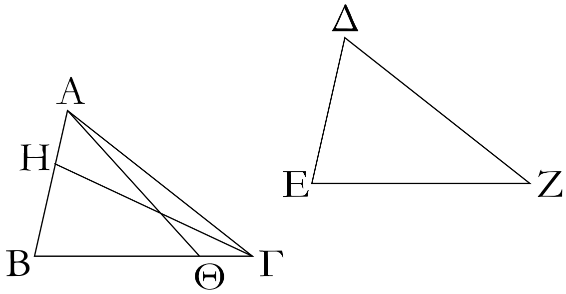
Ἔστω δύο τρίγωνα τὰ ΑΒΓ, ΔΕΖ τὰς δύο γωνίας τὰς ὑπὸ ΑΒΓ, ΒΓΑ δυσὶ ταῖς ὑπὸ ΔΕΖ, ΕΖΔ ἴσας ἔχοντα ἑκατέραν ἑκατέρᾳ, τὴν μὲν ὑπὸ ΑΒΓ τῇ ὑπὸ

Proposition 26

If two triangles have two angles equal to two angles, respectively, and one side equal to one side—in fact, either that by the equal angles, or that subtending one of the equal angles—then (the triangles) will also have the remaining sides equal to the [corresponding] remaining sides, and the remaining angle (equal) to the remaining angle.

Let ABC and DEF be two triangles having the two angles ABC and BCA equal to the two (angles) DEF

ΔΕΖ, τὴν δὲ ὑπὸ ΒΓΑ τῇ ὑπὸ ΕΖΔ· ἐχέτω δὲ καὶ μίαν πλευρὰν μιᾷ πλευρᾷ ἴσην, πρότερον τὴν πρὸς ταῖς ἴσαις γωνίαις τὴν ΒΓ τῇ ΕΖ· λέγω, ὅτι καὶ τὰς λοιπὰς πλευρὰς ταῖς λοιπαῖς πλευραῖς ἴσας ἕξει ἑκατέραν ἑκατέρᾳ, τὴν μὲν ΑΒ τῇ ΔΕ τὴν δὲ ΑΓ τῇ ΔΖ, καὶ τὴν λοιπὴν γωνίαν τῇ λοιπῇ γωνίᾳ, τὴν ὑπὸ ΒΑΓ τῇ ὑπὸ ΕΔΖ.



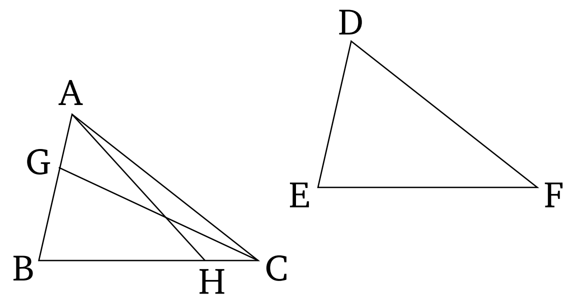
Εἰ γὰρ ἄνισός ἐστιν ἡ ΑΒ τῇ ΔΕ, μία αὐτῶν μείζων ἐστίν. ἔστω μείζων ἡ ΑΒ, καὶ κείσθω τῇ ΔΕ ἴση ἡ ΒΗ, καὶ ἐπεζεύχθω ἡ ΗΓ.

Ἐπεὶ οὖν ἴση ἐστὶν ἡ μὲν ΒΗ τῇ ΔΕ, ἡ δὲ ΒΓ τῇ ΕΖ, δύο δὴ αἱ ΒΗ, ΒΓ δυσὶ ταῖς ΔΕ, ΕΖ ἴσαι εἰσὶν ἑκατέρα ἑκατέρᾳ· καὶ γωνία ἡ ὑπὸ ΗΒΓ γωνίᾳ τῇ ὑπὸ ΔΕΖ ἴση ἐστίν· βάσις ἄρα ἡ ΗΓ βάσει τῇ ΔΖ ἴση ἐστίν, καὶ τὸ ΗΒΓ τρίγωνον τῷ ΔΕΖ τριγώνῳ ἴσον ἐστίν, καὶ αἱ λοιπαὶ γωνίαι ταῖς λοιπαῖς γωνίαις ἴσαι ἔσονται, ὑφ᾿ ἃς αἱ ἴσας πλευραὶ ὑποτείνουσιν· ἴση ἄρα ἡ ὑπὸ ΗΓΒ γωνία τῇ ὑπὸ ΔΖΕ. ἀλλὰ ἡ ὑπὸ ΔΖΕ τῇ ὑπὸ ΒΓΑ ὑπόκειται ἴση· καὶ ἡ ὑπὸ ΒΓΗ ἄρα τῇ ὑπὸ ΒΓΑ ἴση ἐστίν, ἡ ἐλάσσων τῇ μείζονι· ὅπερ ἀδύνατον. οὐκ ἄρα ἄνισός ἐστιν ἡ ΑΒ τῇ ΔΕ. ἴση ἄρα. ἔστι δὲ καὶ ἡ ΒΓ τῇ ΕΖ ἴση· δύο δὴ αἱ ΑΒ, ΒΓ δυσὶ ταῖς ΔΕ, ΕΖ ἴσαι εἰσὶν ἑκατέρα ἑκατέρᾳ· καὶ γωνία ἡ ὑπὸ ΑΒΓ γωνίᾳ τῇ ὑπὸ ΔΕΖ ἐστιν ἴση· βάσις ἄρα ἡ ΑΓ βάσει τῇ ΔΖ ἴση ἐστίν, καὶ λοιπὴ γωνία ἡ ὑπὸ ΒΑΓ τῇ λοιπῇ γωνίᾳ τῇ ὑπὸ ΕΔΖ ἴση ἐστίν.

Ἀλλὰ δὴ πάλιν ἔστωσαν αἱ ὑπὸ τὰς ἴσας γωνίας πλευραὶ ὑποτείνουσαι ἴσαι, ὡς ἡ ΑΒ τῇ ΔΕ· λέγω πάλιν, ὅτι καὶ αἱ λοιπαὶ πλευραὶ ταῖς λοιπαῖς πλευραῖς ἴσας ἔσονται, ἡ μὲν ΑΓ τῇ ΔΖ, ἡ δὲ ΒΓ τῇ ΕΖ καὶ ἔτι ἡ λοιπὴ γωνία ἡ ὑπὸ ΒΑΓ τῇ λοιπῇ γωνίᾳ τῇ ὑπὸ ΕΔΖ ἴση ἐστίν.

Εἰ γὰρ ἄνισός ἐστιν ἡ ΒΓ τῇ ΕΖ, μία αὐτῶν μείζων ἐστίν. ἔστω μείζων, εἰ δυνατόν, ἡ ΒΓ, καὶ κείσθω τῇ ΕΖ ἴση ἡ ΒΘ, καὶ ἐπεζεύχθω ἡ ΑΘ. καὶ ἐπὲι ἴση ἐστὶν ἡ μὲν ΒΘ τῇ ΕΖ ἡ δὲ ΑΒ τῇ ΔΕ, δύο δὴ αἱ ΑΒ, ΒΘ δυσὶ ταῖς ΔΕ, ΕΖ ἴσαι εἰσὶν ἑκατέρα ἑκαρέρᾳ· καὶ γωνίας ἴσας περιέχουσιν· βάσις ἄρα ἡ ΑΘ βάσει τῇ ΔΖ ἴση ἐστίν, καὶ τὸ ΑΒΘ τρίγωνον τῷ ΔΕΖ τριγώνῳ ἴσον ἐστίν, καὶ αἱ λοιπαὶ γωνίαι ταῖς λοιπαῖς γωνίαις ἴσαι ἔσονται, ὑφ᾿ ἃς αἱ ἴσας πλευραὶ ὑποτείνουσιν· ἴση ἄρα ἐστὶν ἡ ὑπὸ ΒΘΑ

and EFD, respectively. (That is) ABC to DEF, and BCA to EFD. And let them also have one side equal to one side. First of all, the (side) by the equal angles. (That is) BC (equal) to EF. I say that the remaining sides will be equal to the corresponding remaining sides. (That is) AB to DE, and AC to DF. And the remaining angle (will be equal) to the remaining angle. (That is) BAC to EDF.



For if AB is unequal to DE then one of them is greater. Let AB be greater, and let BG be made equal to DE [Prop. 1.3], and let GC have been joined.

Therefore, since BG is equal to DE, and BC to EF, the two (straight-lines) GB, $BC^\dagger$ are equal to the two (straight-lines) DE, EF, respectively. And angle GBC is equal to angle DEF. Thus, the base GC is equal to the base DF, and triangle GBC is equal to triangle DEF, and the remaining angles subtended by the equal sides will be equal to the (corresponding) remaining angles [Prop. 1.4]. Thus, GCB (is equal) to DFE. But, DFE was assumed (to be) equal to BCA. Thus, BCG is also equal to BCA, the lesser to the greater. The very thing (is) impossible. Thus, AB is not unequal to DE. Thus, (it is) equal. And BC is also equal to EF. So the two (straight-lines) AB, BC are equal to the two (straight-lines) DE, EF, respectively. And angle ABC is equal to angle DEF. Thus, the base AC is equal to the base DF, and the remaining angle BAC is equal to the remaining angle EDF [Prop. 1.4].

But, again, let the sides subtending the equal angles be equal: for instance, (let) AB (be equal) to DE. Again, I say that the remaining sides will be equal to the remaining sides. (That is) AC to DF, and BC to EF. Furthermore, the remaining angle BAC is equal to the remaining angle EDF.

For if BC is unequal to EF then one of them is greater. If possible, let BC be greater. And let BH be made equal to EF [Prop. 1.3], and let AH have been joined. And since BH is equal to EF, and AB to DE, the two (straight-lines) AB, BH are equal to the two (straight-lines) DE, EF, respectively. And the angles they encompass (are also equal). Thus, the base AH is γωνία τῇ ὑπὸ ΕΖΔ. ἀλλὰ ἡ ὑπὸ ΕΖΔ τῇ ὑπὸ ΒΓΑ ἐστιν ἴση· τριγώνου δὴ τοῦ ΑΘΓ ἡ ἐκτὸς γωνία ἡ ὑπὸ ΒΘΑ ἴση ἐστὶ τῇ ἐντὸς καὶ ἀπεναντίον τῇ ὑπὸ ΒΓΑ· ὅπερ ἀδύνατον. οὐκ ἄρα ἄνισός ἐστιν ἡ ΒΓ τῇ ΕΖ· ἴση ἄρα. ἐστὶ δὲ καὶ ἡ ΑΒ τῇ ΔΕ ἴση. δύο δὴ αἱ ΑΒ, ΒΓ δύο ταῖς ΔΕ, ΕΖ ἴσαι εἰσὶν ἑκατέρα ἑκατέρᾳ· καὶ γωνίας ἴσας περιέχουσι· βάσις ἄρα ἡ ΑΓ βάσει τῇ ΔΖ ἴση ἐστίν, καὶ τὸ ΑΒΓ τρίγωνον τῷ ΔΕΖ τριγώνῳ ἴσον καὶ λοιπὴ γωνία ἡ ὑπὸ ΒΑΓ τῇ λοιπῇ γωνίᾳ τῇ ὑπὸ ΕΔΖ ἴση.

Ἐὰν ἄρα δύο τρίγωνα τὰς δύο γωνίας δυσὶ γωνίαις ἴσας ἔχῃ ἑκαρέραν ἑκαρέρᾳ καὶ μίαν πλευρὰν μιᾷ πλευρᾷ ἴσην ἤτοι τὴν πρὸς ταῖς ἴσαις γωνίαις, ἢ τὴν ὑποτείνουσαν ὑπὸ μίαν τῶν ἴσων γωνιῶν, καὶ τὰς λοιπὰς πλευρὰς ταῖς λοιπαῖς πλευραῖς ἴσας ἕξει καὶ τὴν λοιπὴν γωνίαν τῇ λοιπῇ γωνίᾳ· ὅπερ ἔδει δεῖξαι.

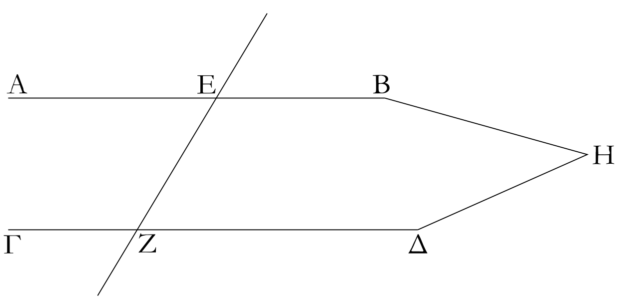
equal to the base DF, and the triangle ABH is equal to the triangle DEF, and the remaining angles subtended by the equal sides will be equal to the (corresponding) remaining angles [Prop. 1.4]. Thus, angle BHA is equal to EFD. But, EFD is equal to BCA. So, for triangle AHC, the external angle BHA is equal to the internal and opposite angle BCA. The very thing (is) impossible [Prop. 1.16]. Thus, BC is not unequal to EF. Thus, (it is) equal. And AB is also equal to DE. So the two (straight-lines) AB, BC are equal to the two (straight-lines) DE, EF, respectively. And they encompass equal angles. Thus, the base AC is equal to the base DF, and triangle ABC (is) equal to triangle DEF, and the remaining angle BAC (is) equal to the remaining angle EDF [Prop. 1.4].

Thus, if two triangles have two angles equal to two angles, respectively, and one side equal to one side—in fact, either that by the equal angles, or that subtending one of the equal angles—then (the triangles) will also have the remaining sides equal to the (corresponding) remaining sides, and the remaining angle (equal) to the remaining angle. (Which is) the very thing it was required to show.

† The Greek text has "BG, BC", which is obviously a mistake.

κζ΄.

Ἐὰν εἰς δύο εὐθείας εὐθεῖα ἐμπίπτουσα τὰς ἐναλλὰξ γωνίας ἴσας ἀλλήλαις ποιῇ, παράλληλοι ἔσονται ἀλλήλαις αἱ εὐθεῖαι.

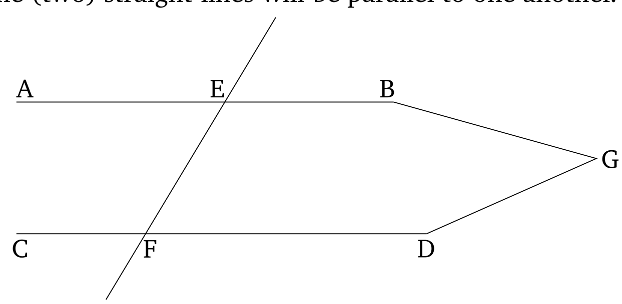


Εἰς γὰρ δύο εὐθείας τὰς ΑΒ, ΓΔ εὐθεῖα ἐμπίπτουσα ἡ ΕΖ τὰς ἐναλλὰξ γωνίας τὰς ὑπὸ ΑΕΖ, ΕΖΔ ἴσας ἀλλήλαις ποιείτω· λέγω, ὅτι παράλληλός ἐστιν ἡ ΑΒ τῇ ΓΔ.

Εἰ γὰρ μή, ἐκβαλλόμεναι αἱ ΑΒ, ΓΔ συμπεσοῦνται ἤτοι ἐπὶ τὰ Β, Δ μέρη ἢ ἐπὶ τὰ Α, Γ. ἐκβεβλήσθωσαν καὶ συμπιπτέτωσαν ἐπὶ τὰ Β, Δ μέρη κατὰ τὸ Η. τριγώνου δὴ τοῦ ΗΕΖ ἡ ἐκτὸς γωνία ἡ ὑπὸ ΑΕΖ ἴση ἐστὶ τῇ ἐντὸς καὶ ἀπεναντίον τῇ ὑπὸ ΕΖΗ· ὅπερ ἐστὶν ἀδύνατον· οὐκ ἄρα αἱ ΑΒ, ΔΓ ἐκβαλλόμεναι συμπεσοῦνται ἐπὶ τὰ Β, Δ μέρη. ὁμοίως δὴ δειχθήσεται, ὅτι οὐδὲ ἐπὶ τὰ Α,

Proposition 27

If a straight-line falling across two straight-lines makes the alternate angles equal to one another then the (two) straight-lines will be parallel to one another.



For let the straight-line EF, falling across the two straight-lines AB and CD, make the alternate angles AEF and EFD equal to one another. I say that AB and CD are parallel.

For if not, being produced, AB and CD will certainly meet together: either in the direction of B and D, or (in the direction) of A and C [Def. 1.23]. Let them have been produced, and let them meet together in the direction of B and D at (point) G. So, for the triangle GEF, the external angle AEF is equal to the interior and opposite (angle) EFG. The very thing is impossible

Γ· αἱ δὲ ἐπὶ μηδέτερα τὰ μέρη συμπίπτουσαι παράλληλοί εἰσιν· παράλληλος ἄρα ἐστὶν ἡ ΑΒ τῇ ΓΔ.

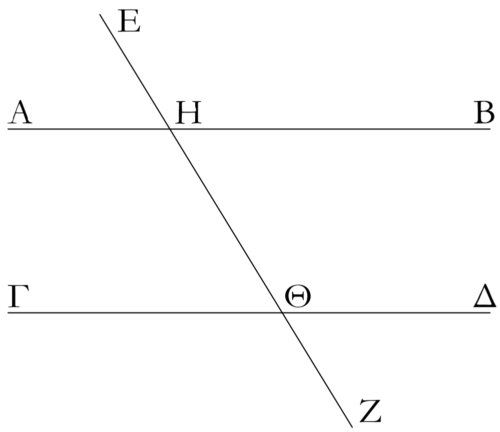
Ἐὰν ἄρα εἰς δύο εὐθείας εὐθεῖα ἐμπίπτουσα τὰς ἐναλλὰξ γωνίας ἴσας ἀλλήλαις ποιῇ, παράλληλοι ἔσονται αἱ εὐθεῖαι· ὅπερ ἔδει δεῖξαι.

[Prop. 1.16]. Thus, being produced, AB and DC will not meet together in the direction of B and D. Similarly, it can be shown that neither (will they meet together) in (the direction of) A and C. But (straight-lines) meeting in neither direction are parallel [Def. 1.23]. Thus, AB and CD are parallel.

Thus, if a straight-line falling across two straight-lines makes the alternate angles equal to one another then the (two) straight-lines will be parallel (to one another). (Which is) the very thing it was required to show.

κη′.

Ἐὰν εἰς δύο εὐθείας εὐθεῖα ἐμπίπτουσα τὴν ἐκτὸς γωνίαν τῇ ἐντὸς καὶ ἀπεναντίον καὶ ἐπὶ τὰ αὐτὰ μέρη ἴσην ποιῇ ἢ τὰς ἐντὸς καὶ ἐπὶ τὰ αὐτὰ μέρη δυσὶν ὀρθαῖς ἴσας, παράλληλοι ἔσονται ἀλλήλαις αἱ εὐθεῖαι.



Εἰς γὰρ δύο εὐθείας τὰς ΑΒ, ΓΔ εὐθεῖα ἐμπίπτουσα ἡ ΕΖ τὴν ἐκτὸς γωνίαν τὴν ὑπὸ ΕΗΒ τῇ ἐντὸς καὶ ἀπεναντίον γωνίᾳ τῇ ὑπὸ ΗΘΔ ἴσην ποιείτω ἢ τὰς ἐντὸς καὶ ἐπὶ τὰ αὐτὰ μέρη τὰς ὑπὸ ΒΗΘ, ΗΘΔ δυσὶν ὀρθαῖς ἴσας· λέγω, ὅτι παράλληλός ἐστιν ἡ ΑΒ τῇ ΓΔ.

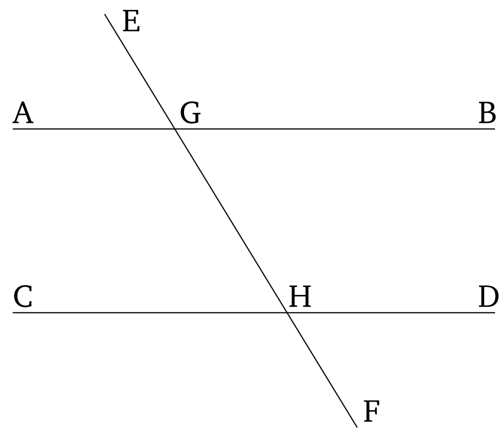
Ἐπεὶ γὰρ ἴση ἐστὶν ἡ ὑπὸ ΕΗΒ τῇ ὑπὸ ΗΘΔ, ἀλλὰ ἡ ὑπὸ ΕΗΒ τῇ ὑπὸ ΑΗΘ ἐστιν ἴση, καὶ ἡ ὑπὸ ΑΗΘ ἄρα τῇ ὑπὸ ΗΘΔ ἐστιν ἴση· καί εἰσιν ἐναλλάξ· παράλληλος ἄρα ἐστὶν ἡ ΑΒ τῇ ΓΔ.

Πάλιν, ἐπεὶ αἱ ὑπὸ ΒΗΘ, ΗΘΔ δύο ὀρθαῖς ἴσαι εἰσίν, εἰσὶ δὲ καὶ αἱ ὑπὸ ΑΗΘ, ΒΗΘ δυσὶν ὀρθαῖς ἴσαι, αἱ ἄρα ὑπὸ ΑΗΘ, ΒΗΘ ταῖς ὑπὸ ΒΗΘ, ΗΘΔ ἴσαι εἰσίν· κοινὴ ἀφῃρήσθω ἡ ὑπὸ ΒΗΘ· λοιπὴ ἄρα ἡ ὑπὸ ΑΗΘ λοιπῇ τῇ ὑπὸ ΗΘΔ ἐστιν ἴση· καί εἰσιν ἐναλλάξ· παράλληλος ἄρα ἐστὶν ἡ ΑΒ τῇ ΓΔ.

Ἐὰν ἄρα εἰς δύο εὐθείας εὐθεῖα ἐμπίπτουσα τὴν ἐκτὸς γωνίαν τῇ ἐντὸς καὶ ἀπεναντίον καὶ ἐπὶ τὰ αὐτὰ μέρη ἴσην ποιῇ ἢ τὰς ἐντὸς καὶ ἐπὶ τὰ αὐτὰ μέρη δυσὶν ὀρθαῖς ἴσας, παράλληλοι ἔσονται αἱ εὐθεῖαι· ὅπερ ἔδει

Proposition 28

If a straight-line falling across two straight-lines makes the external angle equal to the internal and opposite angle on the same side, or (makes) the (sum of the) internal (angles) on the same side equal to two right-angles, then the (two) straight-lines will be parallel to one another.



For let EF, falling across the two straight-lines AB and CD, make the external angle EGB equal to the internal and opposite angle GHD, or the (sum of the) internal (angles) on the same side, BGH and GHD, equal to two right-angles. I say that AB is parallel to CD.

For since (in the first case) EGB is equal to GHD, but EGB is equal to AGH [Prop. 1.15], AGH is thus also equal to GHD. And they are alternate (angles). Thus, AB is parallel to CD [Prop. 1.27].

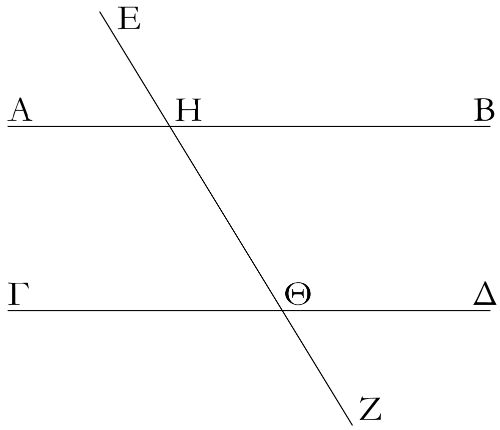
Again, since (in the second case, the sum of) BGH and GHD is equal to two right-angles, and (the sum of) AGH and BGH is also equal to two right-angles [Prop. 1.13], (the sum of) AGH and BGH is thus equal to (the sum of) BGH and GHD. Let BGH have been subtracted from both. Thus, the remainder AGH is equal to the remainder GHD. And they are alternate (angles). Thus, AB is parallel to CD [Prop. 1.27].

Thus, if a straight-line falling across two straight-lines makes the external angle equal to the internal and oppoδεῖξαι.

site angle on the same side, or (makes) the (sum of the) internal (angles) on the same side equal to two right-angles, then the (two) straight-lines will be parallel (to one another). (Which is) the very thing it was required to show.

κθ΄.

Ἡ εἰς τὰς παραλλήλους εὐθείας εὐθεῖα ἐμπίπτουσα τάς τε ἐναλλὰξ γωνίας ἴσας ἀλλήλαις ποιεῖ καὶ τὴν ἐκτὸς τῇ ἐντὸς καὶ ἀπεναντίον ἴσην καὶ τὰς ἐντὸς καὶ ἐπὶ τὰ αὐτὰ μέρη δυσὶν ὀρθαῖς ἴσας.



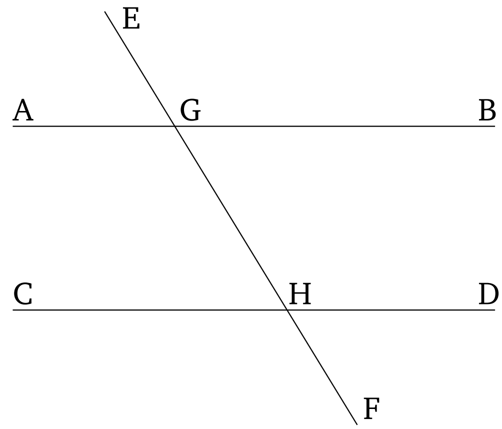
Εἰς γὰρ παραλλήλους εὐθείας τὰς ΑΒ, ΓΔ εὐθεῖα ἐμπιπτέτω ἡ ΕΖ· λέγω, ὅτι τὰς ἐναλλὰξ γωνίας τὰς ὑπὸ ΑΗΘ, ΗΘΔ ἴσας ποιεῖ καὶ τὴν ἐκτὸς γωνίαν τὴν ὑπὸ ΕΗΒ τῇ ἐντὸς καὶ ἀπεναντίον τῇ ὑπὸ ΗΘΔ ἴσην καὶ τὰς ἐντὸς καὶ ἐπὶ τὰ αὐτὰ μέρη τὰς ὑπὸ ΒΗΘ, ΗΘΔ δυσὶν ὀρθαῖς ἴσας.

Εἰ γὰρ ἄνισός ἐστιν ἡ ὑπὸ ΑΗΘ τῇ ὑπὸ ΗΘΔ, μία αὐτῶν μείζων ἐστίν. ἔστω μείζων ἡ ὑπὸ ΑΗΘ· κοινὴ προσκείσθω ἡ ὑπὸ ΒΗΘ· αἱ ἄρα ὑπὸ ΑΗΘ, ΒΗΘ τῶν ὑπὸ ΒΗΘ, ΗΘΔ μείζονές εἰσιν. ἀλλὰ αἱ ὑπὸ ΑΗΘ, ΒΗΘ δυσὶν ὀρθαῖς ἴσαι εἰσίν. [καὶ] αἱ ἄρα ὑπὸ ΒΗΘ, ΗΘΔ δύο ὀρθῶν ἐλάσσονές εἰσιν. αἱ δὲ ἀπ᾿ ἐλασσόνων ἢ δύο ὀρθῶν ἐκβαλλόμεναι εἰς ἄπειρον συμπίπουσιν· αἱ ἄρα ΑΒ, ΓΔ ἐκβαλλόμεναι εἰς ἄπειρον συμπεσοῦνται· οὐ συμπίπτουσι δὲ διὰ τὸ παραλλήλους αὐτὰς ὑποκεῖσθαι· οὐκ ἄρα ἄνισός ἐστιν ἡ ὑπὸ ΑΗΘ τῇ ὑπὸ ΗΘΔ· ἴση ἄρα. ἀλλὰ ἡ ὑπὸ ΑΗΘ τῇ ὑπὸ ΕΗΒ ἐστιν ἴση· καὶ ἡ ὑπὸ ΕΗΒ ἄρα τῇ ὑπὸ ΗΘΔ ἐστιν ἴση· κοινὴ προσκείσθω ἡ ὑπὸ ΒΗΘ· αἱ ἄρα ὑπὸ ΕΗΒ, ΒΗΘ ταῖς ὑπὸ ΒΗΘ, ΗΘΔ ἴσαι εἰσίν. ἀλλὰ αἱ ὑπὸ ΕΗΒ, ΒΗΘ δύο ὀρθαῖς ἴσαι εἰσίν· καὶ αἱ ὑπὸ ΒΗΘ, ΗΘΔ ἄρα δύο ὀρθαῖς ἴσαι εἰσίν.

Ἡ ἄρα εἰς τὰς παραλλήλους εὐθείας εὐθεῖα ἐμπίπτουσα τάς τε ἐναλλὰξ γωνίας ἴσας ἀλλήλαις ποιεῖ καὶ τὴν ἐκτὸς

Proposition 29

A straight-line falling across parallel straight-lines makes the alternate angles equal to one another, the external (angle) equal to the internal and opposite (angle), and the (sum of the) internal (angles) on the same side equal to two right-angles.



For let the straight-line EF fall across the parallel straight-lines AB and CD. I say that it makes the alternate angles, AGH and GHD, equal, the external angle EGB equal to the internal and opposite (angle) GHD, and the (sum of the) internal (angles) on the same side, BGH and GHD, equal to two right-angles.

For if AGH is unequal to GHD then one of them is greater. Let AGH be greater. Let BGH have been added to both. Thus, (the sum of) AGH and BGH is greater than (the sum of) BGH and GHD. But, (the sum of) AGH and BGH is equal to two right-angles [Prop 1.13]. Thus, (the sum of) BGH and GHD is [also] less than two right-angles. But (straight-lines) being produced to infinity from (internal angles whose sum is) less than two right-angles meet together [Post. 5]. Thus, AB and CD, being produced to infinity, will meet together. But they do not meet, on account of them (initially) being assumed parallel (to one another) [Def. 1.23]. Thus, AGH is not unequal to GHD. Thus, (it is) equal. But, AGH is equal to EGB [Prop. 1.15]. And EGB is thus also equal to GHD. Let BGH be added to both. Thus, (the sum of) EGB and BGH is equal to (the sum of) BGH and GHD. But, (the sum of) EGB and BGH is equal to two right-angles [Prop. 1.13]. Thus, (the sum of) BGH and GHD

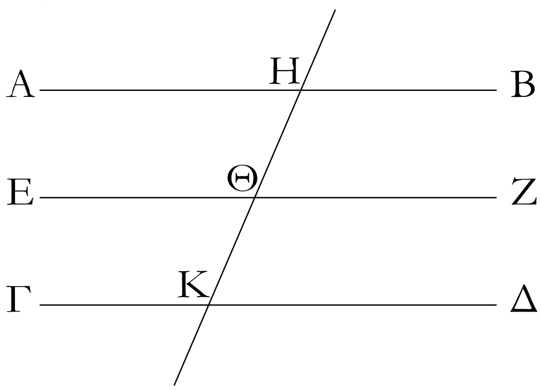
τῇ ἐντὸς καὶ ἀπεναντίον ἴσην καὶ τὰς ἐντὸς καὶ ἐπὶ τὰ αὐτὰ μέρη δυσὶν ὀρθαῖς ἴσας· ὅπερ ἔδει δεῖξαι.

is also equal to two right-angles.

Thus, a straight-line falling across parallel straight-lines makes the alternate angles equal to one another, the external (angle) equal to the internal and opposite (angle), and the (sum of the) internal (angles) on the same side equal to two right-angles. (Which is) the very thing it was required to show.

λ΄.

Αἱ τῇ αὐτῇ εὐθείᾳ παράλληλοι καὶ ἀλλήλαις εἰσὶ παράλληλοι.



Ἔστω ἑκατέρα τῶν ΑΒ, ΓΔ τῇ ΕΖ παράλληλος· λέγω, ὅτι καὶ ἡ ΑΒ τῇ ΓΔ ἐστι παράλληλος.

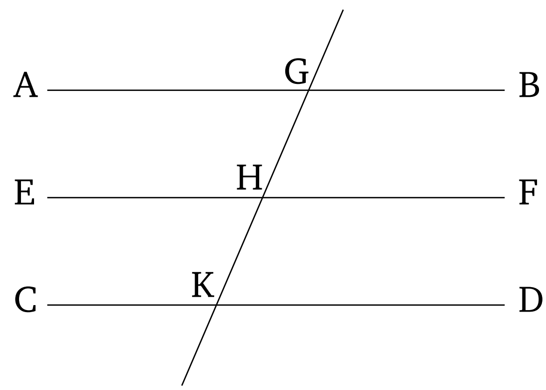
Ἐμπιπτέτω γὰρ εἰς αὐτὰς εὐθεῖα ἡ ΗΚ.

Καὶ ἐπεὶ εἰς παραλλήλους εὐθείας τὰς ΑΒ, ΕΖ εὐθεῖα ἐμπέπτωκεν ἡ ΗΚ, ἴση ἄρα ἡ ὑπὸ ΑΗΚ τῇ ὑπὸ ΗΘΖ. πάλιν, ἐπεὶ εἰς παραλλήλους εὐθείας τὰς ΕΖ, ΓΔ εὐθεῖα ἐμπέπτωκεν ἡ ΗΚ, ἴση ἐστὶν ἡ ὑπὸ ΗΘΖ τῇ ὑπὸ ΗΚΔ. ἐδείχθη δὲ καὶ ἡ ὑπὸ ΑΗΚ τῇ ὑπὸ ΗΘΖ ἴση. καὶ ἡ ὑπὸ ΑΗΚ ἄρα τῇ ὑπὸ ΗΚΔ ἐστιν ἴση· καί εἰσιν ἐναλλάξ. παράλληλος ἄρα ἐστὶν ἡ ΑΒ τῇ ΓΔ.

[Αἱ ἄρα τῇ αὐτῇ εὐθείᾳ παράλληλοι καὶ ἀλλήλαις εἰσὶ παράλληλοι·] ὅπερ ἔδει δεῖξαι.

Proposition 30

(Straight-lines) parallel to the same straight-line are also parallel to one another.



Let each of the (straight-lines) AB and CD be parallel to EF. I say that AB is also parallel to CD.

For let the straight-line GK fall across (AB, CD, and EF).

And since GK has fallen across the parallel straight-lines AB and EF, (angle) AGK (is) thus equal to GHF [Prop. 1.29]. Again, since GK has fallen across the parallel straight-lines EF and CD, (angle) GHF is equal to GKD [Prop. 1.29]. But AGK was also shown (to be) equal to GHF. Thus, AGK is also equal to GKD. And they are alternate (angles). Thus, AB is parallel to CD [Prop. 1.27].

[Thus, (straight-lines) parallel to the same straight-line are also parallel to one another.] (Which is) the very thing it was required to show.

λα΄.

Διὰ τοῦ δοθέντος σημείου τῇ δοθείσῃ εὐθείᾳ παράλληλον εὐθεῖαν γραμμὴν ἀγαγεῖν.

Ἔστω τὸ μὲν δοθὲν σημεῖον τὸ Α, ἡ δὲ δοθεῖσα εὐθεῖα ἡ ΒΓ· δεῖ δὴ διὰ τοῦ Α σημείου τῇ ΒΓ εὐθείᾳ παράλληλον εὐθεῖαν γραμμὴν ἀγαγεῖν.

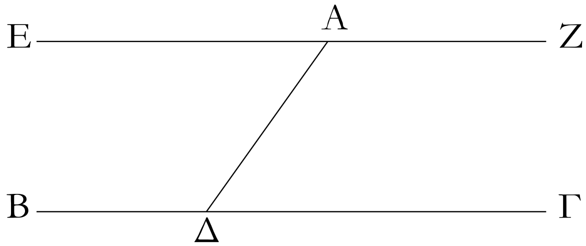
Εἰλήφθω ἐπὶ τῆς ΒΓ τυχὸν σημεῖον τὸ Δ, καὶ ἐπεζεύχθω ἡ ΑΔ· καὶ συνεστάτω πρὸς τῇ ΔΑ εὐθείᾳ καὶ τῷ πρὸς αὐτῇ σημείῳ τῷ Α τῇ ὑπὸ ΑΔΓ γωνίᾳ ἴση ἡ ὑπὸ ΔΑΕ· καὶ ἐκβεβλήσθω ἐπ᾽ εὐθείας τῇ ΕΑ εὐθεῖα

Proposition 31

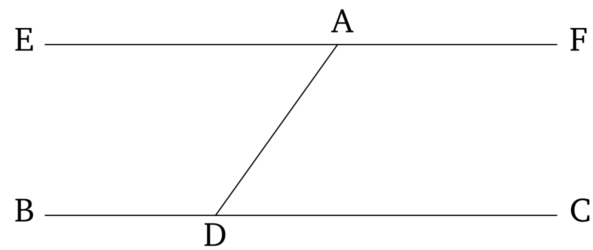
To draw a straight-line parallel to a given straight-line, through a given point.

Let A be the given point, and BC the given straight-line. So it is required to draw a straight-line parallel to the straight-line BC, through the point A.

Let the point D have been taken somewhere on BC, and let AD have been joined. And let (angle) DAE, equal to angle ADC, have been constructed at the point A on the straight-line DA [Prop. 1.23]. And let the ἡ ΑΖ.



straight-line AF have been produced in a straight-line with EA.



Καὶ ἐπεὶ εἰς δύο εὐθείας τὰς ΒΓ, ΕΖ εὐθεῖα ἐμπίπτουσα ἡ ΑΔ τὰς ἐναλλὰξ γωνίας τὰς ὑπὸ ΕΑΔ, ΑΔΓ ἴσας ἀλλήλαις πεποίηκεν, παράλληλος ἄρα ἐστὶν ἡ ΕΑΖ τῇ ΒΓ.

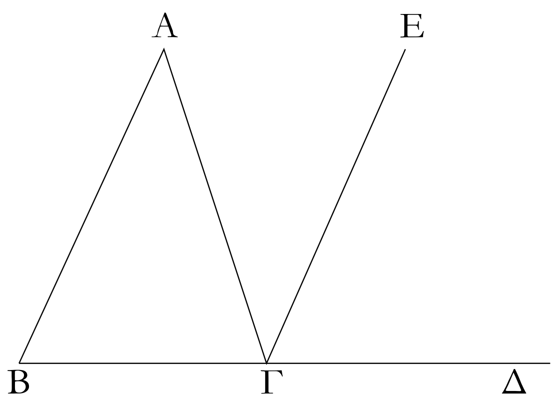
Διὰ τοῦ δοθέντος ἄρα σημείου τοῦ Α τῇ δοθείσῃ εὐθείᾳ τῇ ΒΓ παράλληλος εὐθεῖα γραμμὴ ἦκται ἡ ΕΑΖ· ὅπερ ἔδει ποιῆσαι.

And since the straight-line AD, (in) falling across the two straight-lines BC and EF, has made the alternate angles EAD and ADC equal to one another, EAF is thus parallel to BC [Prop. 1.27].

Thus, the straight-line EAF has been drawn parallel to the given straight-line BC, through the given point A. (Which is) the very thing it was required to do.

λβ΄.

Παντὸς τριγώνου μιᾶς τῶν πλευρῶν προσεκβληθείσης ἡ ἐκτὸς γωνία δυσὶ ταῖς ἐντὸς καὶ ἀπεναντίον ἴση ἐστίν, καὶ αἱ ἐντὸς τοῦ τριγώνου τρεῖς γωνίαι δυσὶν ὀρθαῖς ἴσαι εἰσίν.



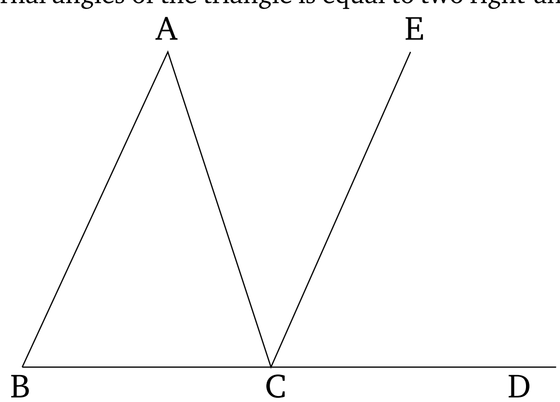
Ἔστω τρίγωνον τὸ ΑΒΓ, καὶ προσεκβεβλήσθω αὐτοῦ μία πλευρὰ ἡ ΒΓ ἐπὶ τὸ Δ· λέγω, ὅτι ἡ ἐκτὸς γωνία ἡ ὑπὸ ΑΓΔ ἴση ἐστὶ δυσὶ ταῖς ἐντὸς καὶ ἀπεναντίον ταῖς ὑπὸ ΓΑΒ, ΑΒΓ, καὶ αἱ ἐντὸς τοῦ τριγώνου τρεῖς γωνίαι αἱ ὑπὸ ΑΒΓ, ΒΓΑ, ΓΑΒ δυσὶν ὀρθαῖς ἴσαι εἰσίν.

Ἤχθω γὰρ διὰ τοῦ Γ σημείου τῇ ΑΒ εὐθείᾳ παράλληλος ἡ ΓΕ.

Καὶ ἐπεὶ παράλληλός ἐστιν ἡ ΑΒ τῇ ΓΕ, καὶ εἰς αὐτὰς ἐμπέπτωκεν ἡ ΑΓ, αἱ ἐναλλὰξ γωνίαι αἱ ὑπὸ ΒΑΓ, ΑΓΕ ἴσαι ἀλλήλαις εἰσίν. πάλιν, ἐπεὶ παράλληλός ἐστιν ἡ ΑΒ τῇ ΓΕ, καὶ εἰς αὐτὰς ἐμπέπτωκεν εὐθεῖα ἡ ΒΔ, ἡ ἐκτὸς γωνία ἡ ὑπὸ ΕΓΔ ἴση ἐστὶ τῇ ἐντὸς καὶ ἀπεναντίον τῇ ὑπὸ ΑΒΓ. ἐδείχθη δὲ καὶ ἡ ὑπὸ ΑΓΕ τῇ ὑπὸ ΒΑΓ ἴση· ὅλη ἄρα ἡ ὑπὸ ΑΓΔ γωνία ἴση ἐστὶ δυσὶ ταῖς ἐντὸς

Proposition 32

For any triangle, (if) one of the sides (is) produced (then) the external angle is equal to the (sum of the) two internal and opposite (angles), and the (sum of the) three internal angles of the triangle is equal to two right-angles.



Let ABC be a triangle, and let one of its sides BC have been produced to D. I say that the external angle ACD is equal to the (sum of the) two internal and opposite angles CAB and ABC, and the (sum of the) three internal angles of the triangle—ABC, BCA, and CAB—is equal to two right-angles.

For let CE have been drawn through point C parallel to the straight-line AB [Prop. 1.31].

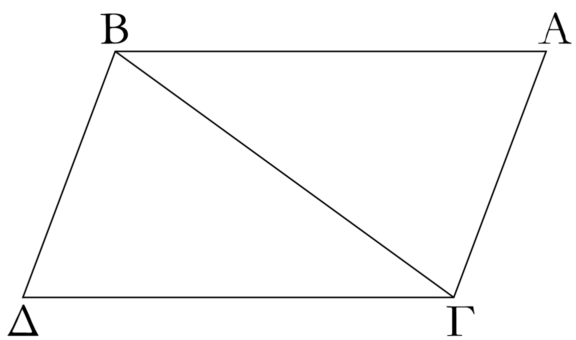
And since AB is parallel to CE, and AC has fallen across them, the alternate angles BAC and ACE are equal to one another [Prop. 1.29]. Again, since AB is parallel to CE, and the straight-line BD has fallen across them, the external angle ECD is equal to the internal and opposite (angle) ABC [Prop. 1.29]. But ACE was also shown (to be) equal to BAC. Thus, the whole an-καὶ ἀπεναντίον ταῖς ὑπὸ ΒΑΓ, ΑΒΓ.

Κοινὴ προσκείσθω ἡ ὑπὸ ΑΓΒ· αἱ ἄρα ὑπὸ ΑΓΔ, ΑΓΒ τρισὶ ταῖς ὑπὸ ΑΒΓ, ΒΓΑ, ΓΑΒ ἴσαι εἰσίν. ἀλλ᾿ αἱ ὑπὸ ΑΓΔ, ΑΓΒ δυσὶν ὀρθαῖς ἴσαι εἰσίν· καὶ αἱ ὑπὸ ΑΓΒ, ΓΒΑ, ΓΑΒ ἄρα δυσὶν ὀρθαῖς ἴσαι εἰσίν.

Παντὸς ἄρα τριγώνου μιᾶς τῶν πλευρῶν προσεκβληθείσης ἡ ἐκτὸς γωνία δυσὶ ταῖς ἐντὸς καὶ ἀπεναντίον ἴση ἐστίν, καὶ αἱ ἐντὸς τοῦ τριγώνου τρεῖς γωνίαι δυσὶν ὀρθαῖς ἴσαι εἰσίν· ὅπερ ἔδει δεῖξαι.

λγ΄.

Αἱ τὰς ἴσας τε καὶ παραλλήλους ἐπὶ τὰ αὐτὰ μέρη ἐπιζευγνύουσαι εὐθεῖαι καὶ αὐταὶ ἴσας τε καὶ παράλληλοί εἰσιν.



Ἔστωσαν ἴσαι τε καὶ παράλληλοι αἱ ΑΒ, ΓΔ, καὶ ἐπιζευγνύτωσαν αὐτὰς ἐπὶ τὰ αὐτὰ μέρη εὐθεῖαι αἱ ΑΓ, ΒΔ· λέγω, ὅτι καὶ αἱ ΑΓ, ΒΔ ἴσαι τε καὶ παράλληλοί εἰσιν.

Ἐπεζεύχθω ἡ ΒΓ. καὶ ἐπεὶ παράλληλός ἐστιν ἡ ΑΒ τῇ ΓΔ, καὶ εἰς αὐτὰς ἐμπέπτωκεν ἡ ΒΓ, αἱ ἐναλλὰξ γωνίαι αἱ ὑπὸ ΑΒΓ, ΒΓΔ ἴσαι ἀλλήλαις εἰσίν. καὶ ἐπεὶ ἴση ἐστὶν ἡ ΑΒ τῇ ΓΔ κοινὴ δὲ ἡ ΒΓ, δύο δὴ αἱ ΑΒ, ΒΓ δύο ταῖς ΒΓ, ΓΔ ἴσαι εἰσίν· καὶ γωνία ἡ ὑπὸ ΑΒΓ γωνίᾳ τῇ ὑπὸ ΒΓΔ ἴση· βάσις ἄρα ἡ ΑΓ βάσει τῇ ΒΔ ἐστιν ἴση, καὶ τὸ ΑΒΓ τρίγωνον τῷ ΒΓΔ τριγώνῳ ἴσον ἐστίν, καὶ αἱ λοιπαὶ γωνίαι ταῖς λοιπαῖς γωνίαις ἴσαι ἔσονται ἑκατέρα ἑκατέρᾳ, ὑφ᾿ ἃς αἱ ἴσαι πλευραὶ ὑποτείνουσιν· ἴση ἄρα ἡ ὑπὸ ΑΓΒ γωνία τῇ ὑπὸ ΓΒΔ. καὶ ἐπεὶ εἰς δύο εὐθείας τὰς ΑΓ, ΒΔ εὐθεῖα ἐμπίπτουσα ἡ ΒΓ τὰς ἐναλλὰξ γωνίας ἴσας ἀλλήλαις πεποίηκεν, παράλληλος ἄρα ἐστὶν ἡ ΑΓ τῇ ΒΔ. ἐδείχθη δὲ αὐτῇ καὶ ἴση.

Αἱ ἄρα τὰς ἴσας τε καὶ παραλλήλους ἐπὶ τὰ αὐτὰ μέρη ἐπιζευγνύουσαι εὐθεῖαι καὶ αὐταὶ ἴσαι τε καὶ παράλληλοί εἰσιν· ὅπερ ἔδει δεῖξαι.

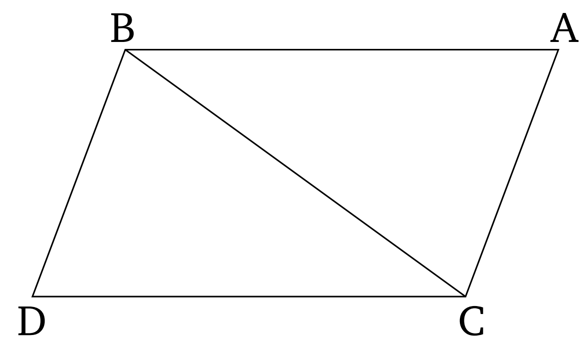
gle ACD is equal to the (sum of the) two internal and opposite (angles) BAC and ABC.

Let ACB have been added to both. Thus, (the sum of) ACD and ACB is equal to the (sum of the) three (angles) ABC, BCA, and CAB. But, (the sum of) ACD and ACB is equal to two right-angles [Prop. 1.13]. Thus, (the sum of) ACB, CBA, and CAB is also equal to two right-angles.

Thus, for any triangle, (if) one of the sides (is) produced (then) the external angle is equal to the (sum of the) two internal and opposite (angles), and the (sum of the) three internal angles of the triangle is equal to two right-angles. (Which is) the very thing it was required to show.

Proposition 33

Straight-lines joining equal and parallel (straight-lines) on the same sides are themselves also equal and parallel.



Let AB and CD be equal and parallel (straight-lines), and let the straight-lines AC and BD join them on the same sides. I say that AC and BD are also equal and parallel.

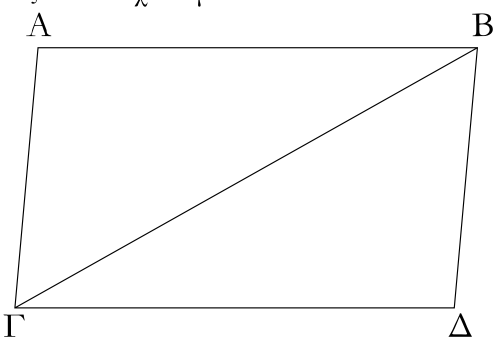
Let BC have been joined. And since AB is parallel to CD, and BC has fallen across them, the alternate angles ABC and BCD are equal to one another [Prop. 1.29]. And since AB and CD are equal, and BC is common, the two (straight-lines) AB, BC are equal to the two (straight-lines) DC, CB.†And the angle ABC is equal to the angle BCD. Thus, the base AC is equal to the base BD, and triangle ABC is equal to triangle ACD, and the remaining angles will be equal to the corresponding remaining angles subtended by the equal sides [Prop. 1.4]. Thus, angle ACB is equal to CBD. Also, since the straight-line BC, (in) falling across the two straight-lines AC and BD, has made the alternate angles (ACB and CBD) equal to one another, AC is thus parallel to BD [Prop. 1.27]. And (AC) was also shown (to be) equal to (BD).

Thus, straight-lines joining equal and parallel (straight-lines) on the same sides are themselves also equal and parallel. (Which is) the very thing it was required to show.

† The Greek text has “BC, CD”, which is obviously a mistake.

λδ΄.

Τῶν παραλληλογράμμων χωρίων αἱ ἀπεναντίον πλευραί τε καὶ γωνίαι ἴσαι ἀλλήλαις εἰσίν, καὶ ἡ διάμετρος αὐτὰ δίχα τέμνει.



Ἔστω παραλληλόγραμμον χωρίον τὸ ΑΓΔΒ, διάμετρος δὲ αὐτοῦ ἡ ΒΓ· λέγω, ὅτι τοῦ ΑΓΔΒ παραλληλογράμμου αἱ ἀπεναντίον πλευραί τε καὶ γωνίαι ἴσαι ἀλλήλαις εἰσίν, καὶ ἡ ΒΓ διάμετρος αὐτὸ δίχα τέμνει.

Ἐπεὶ γὰρ παράλληλός ἐστιν ἡ ΑΒ τῇ ΓΔ, καὶ εἰς αὐτὰς ἐμπέπτωκεν εὐθεῖα ἡ ΒΓ, αἱ ἐναλλὰξ γωνίαι αἱ ὑπὸ ΑΒΓ, ΒΓΔ ἴσαι ἀλλήλαις εἰσίν. πάλιν ἐπεὶ παράλληλός ἐστιν ἡ ΑΓ τῇ ΒΔ, καὶ εἰς αὐτὰς ἐμπέπτωκεν ἡ ΒΓ, αἱ ἐναλλὰξ γωνίαι αἱ ὑπὸ ΑΓΒ, ΓΒΔ ἴσας ἀλλήλαις εἰσίν. δύο δὴ τρίγωνά ἐστι τὰ ΑΒΓ, ΒΓΔ τὰς δύο γωνίας τὰς ὑπὸ ΑΒΓ, ΒΓΑ δυσὶ ταῖς ὑπὸ ΒΓΔ, ΓΒΔ ἴσας ἔχοντα ἑκατέραν ἑκατέρᾳ καὶ μίαν πλευρὰν μιᾷ πλευρᾷ ἴσην τὴν πρὸς ταῖς ἴσαις γωνίαις κοινὴν αὐτῶν τὴν ΒΓ· καὶ τὰς λοιπὰς ἄρα πλευρὰς ταῖς λοιπαῖς ἴσας ἕξει ἑκατέραν ἑκατέρᾳ καὶ τὴν λοιπὴν γωνίαν τῇ λοιπῇ γωνίᾳ· ἴση ἄρα ἡ μὲν ΑΒ πλευρὰ τῇ ΓΔ, ἡ δὲ ΑΓ τῇ ΒΔ, καὶ ἔτι ἴση ἐστὶν ἡ ὑπὸ ΒΑΓ γωνία τῇ ὑπὸ ΓΔΒ. καὶ ἐπεὶ ἴση ἐστὶν ἡ μὲν ὑπὸ ΑΒΓ γωνία τῇ ὑπὸ ΒΓΔ, ἡ δὲ ὑπὸ ΓΒΔ τῇ ὑπὸ ΑΓΒ, ὅλη ἄρα ἡ ὑπὸ ΑΒΔ ὅλῃ τῇ ὑπὸ ΑΓΔ ἐστιν ἴση. ἐδείχθη δὲ καὶ ἡ ὑπὸ ΒΑΓ τῇ ὑπὸ ΓΔΒ ἴση.

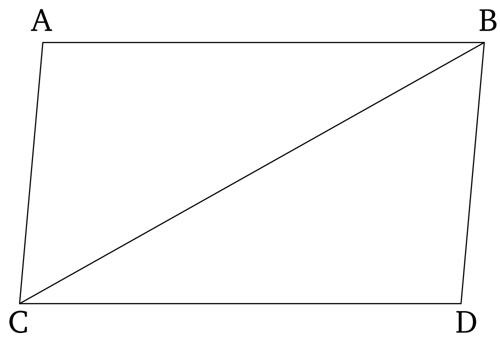
Τῶν ἄρα παραλληλογράμμων χωρίων αἱ ἀπεναντίον πλευραί τε καὶ γωνίαι ἴσαι ἀλλήλαις εἰσίν.

Λέγω δή, ὅτι καὶ ἡ διάμετρος αὐτὰ δίχα τέμνει. ἐπεὶ γὰρ ἴση ἐστὶν ἡ ΑΒ τῇ ΓΔ, κοινὴ δὲ ἡ ΒΓ, δύο δὴ αἱ ΑΒ, ΒΓ δυσὶ ταῖς ΓΔ, ΒΓ ἴσαι εἰσὶν ἑκατέρα ἑκατέρᾳ· καὶ γωνία ἡ ὑπὸ ΑΒΓ γωνίᾳ τῇ ὑπὸ ΒΓΔ ἴση. καὶ βάσις ἄρα ἡ ΑΓ τῇ ΔΒ ἴση. καὶ τὸ ΑΒΓ [ἄρα] τρίγωνον τῷ ΒΓΔ τριγώνῳ ἴσον ἐστίν.

Ἡ ἄρα ΒΓ διάμετρος δίχα τέμνει τὸ ΑΒΓΔ παραλληλόγραμμον· ὅπερ ἔδει δεῖξαι.

Proposition 34

For parallelogrammic figures, the opposite sides and angles are equal to one another, and a diagonal cuts them in half.



Let $ACDB$ be a parallelogrammic figure, and BC its diagonal. I say that for parallelogram $ACDB$, the opposite sides and angles are equal to one another, and the diagonal BC cuts it in half.

For since AB is parallel to CD, and the straight-line BC has fallen across them, the alternate angles ABC and BCD are equal to one another [Prop. 1.29]. Again, since AC is parallel to BD, and BC has fallen across them, the alternate angles ACB and CBD are equal to one another [Prop. 1.29]. So ABC and BCD are two triangles having the two angles ABC and BCA equal to the two (angles) BCD and CBD, respectively, and one side equal to one side—the (one) common to the equal angles, (namely) BC. Thus, they will also have the remaining sides equal to the corresponding remaining (sides), and the remaining angle (equal) to the remaining angle [Prop. 1.26]. Thus, side AB is equal to CD, and AC to BD. Furthermore, angle BAC is equal to CDB. And since angle ABC is equal to BCD, and CBD to ACB, the whole (angle) ABD is thus equal to the whole (angle) ACD. And BAC was also shown (to be) equal to CDB.

Thus, for parallelogrammic figures, the opposite sides and angles are equal to one another.

And, I also say that a diagonal cuts them in half. For since AB is equal to CD, and BC (is) common, the two (straight-lines) AB, BC are equal to the two (straight-lines) DC, CB†, respectively. And angle ABC is equal to angle BCD. Thus, the base AC (is) also equal to DB [Prop. 1.4]. Also, triangle ABC is equal to triangle BCD [Prop. 1.4].

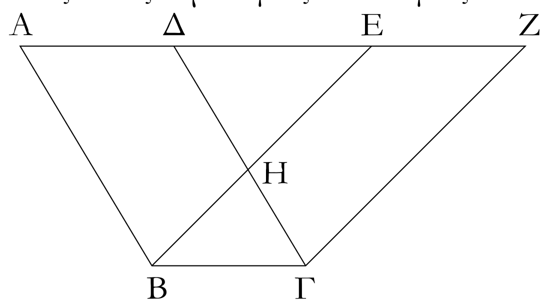
Thus, the diagonal BC cuts the parallelogram $ACDB$[‡] in half. (Which is) the very thing it was required to show.

[†] The Greek text has "CD, BC", which is obviously a mistake.

[‡] The Greek text has "$ABCD$", which is obviously a mistake.

λε΄.

Τὰ παραλληλόγραμμα τὰ ἐπὶ τῆς αὐτῆς βάσεως ὄντα καὶ ἐν ταῖς αὐταῖς παραλλήλοις ἴσα ἀλλήλοις ἐστίν.



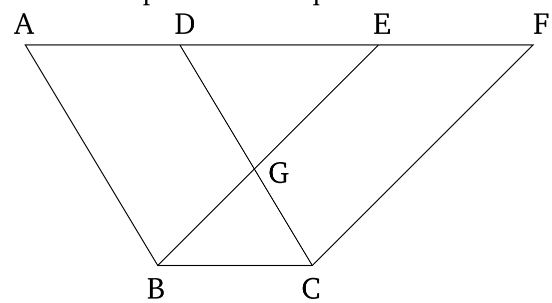
Ἔστω παραλληλόγραμμα τὰ ΑΒΓΔ, ΕΒΓΖ ἐπὶ τῆς αὐτῆς βάσεως τῆς ΒΓ καὶ ἐν ταῖς αὐταῖς παραλλήλοις ταῖς ΑΖ, ΒΓ· λέγω, ὅτι ἴσον ἐστὶ τὸ ΑΒΓΔ τῷ ΕΒΓΖ παραλληλογράμμῳ.

Ἐπεὶ γὰρ παραλληλόγραμμόν ἐστι τὸ ΑΒΓΔ, ἴση ἐστὶν ἡ ΑΔ τῇ ΒΓ. διὰ τὰ αὐτὰ δὴ καὶ ἡ ΕΖ τῇ ΒΓ ἐστιν ἴση· ὥστε καὶ ἡ ΑΔ τῇ ΕΖ ἐστιν ἴση· καὶ κοινὴ ἡ ΔΕ· ὅλη ἄρα ἡ ΑΕ ὅλῃ τῇ ΔΖ ἐστιν ἴση. ἔστι δὲ καὶ ἡ ΑΒ τῇ ΔΓ ἴση· δύο δὴ αἱ ΕΑ, ΑΒ δύο ταῖς ΖΔ, ΔΓ ἴσαι εἰσὶν ἑκατέρα ἑκατέρᾳ· καὶ γωνία ἡ ὑπὸ ΖΔΓ γωνίᾳ τῇ ὑπὸ ΕΑΒ ἐστιν ἴση ἡ ἐκτὸς τῇ ἐντός· βάσις ἄρα ἡ ΕΒ βάσει τῇ ΖΓ ἴση ἐστίν, καὶ τὸ ΕΑΒ τρίγωνον τῷ ΔΖΓ τριγώνῳ ἴσον ἔσται· κοινὸν ἀφῃρήσθω τὸ ΔΗΕ· λοιπὸν ἄρα τὸ ΑΒΗΔ τραπέζιον λοιπῷ τῷ ΕΗΓΖ τραπεζίῳ ἐστὶν ἴσον· κοινὸν προσκείσθω τὸ ΗΒΓ τρίγωνον· ὅλον ἄρα τὸ ΑΒΓΔ παραλληλόγραμμον ὅλῳ τῷ ΕΒΓΖ παραλληλογράμμῳ ἴσον ἐστίν.

Τὰ ἄρα παραλληλόγραμμα τὰ ἐπὶ τῆς αὐτῆς βάσεως ὄντα καὶ ἐν ταῖς αὐταῖς παραλλήλοις ἴσα ἀλλήλοις ἐστίν· ὅπερ ἔδει δεῖξαι.

Proposition 35

Parallelograms which are on the same base and between the same parallels are equal[†] to one another.



Let $ABCD$ and $EBCF$ be parallelograms on the same base BC, and between the same parallels AF and BC. I say that $ABCD$ is equal to parallelogram $EBCF$.

For since $ABCD$ is a parallelogram, AD is equal to BC [Prop. 1.34]. So, for the same (reasons), EF is also equal to BC. So AD is also equal to EF. And DE is common. Thus, the whole (straight-line) AE is equal to the whole (straight-line) DF. And AB is also equal to DC. So the two (straight-lines) EA, AB are equal to the two (straight-lines) FD, DC, respectively. And angle FDC is equal to angle EAB, the external to the internal [Prop. 1.29]. Thus, the base EB is equal to the base FC, and triangle EAB will be equal to triangle DFC [Prop. 1.4]. Let DGE have been taken away from both. Thus, the remaining trapezium $ABGD$ is equal to the remaining trapezium $EGCF$. Let triangle GBC have been added to both. Thus, the whole parallelogram $ABCD$ is equal to the whole parallelogram $EBCF$.

Thus, parallelograms which are on the same base and between the same parallels are equal to one another. (Which is) the very thing it was required to show.

[†] Here, for the first time, "equal" means "equal in area", rather than "congruent".

λϛ΄.

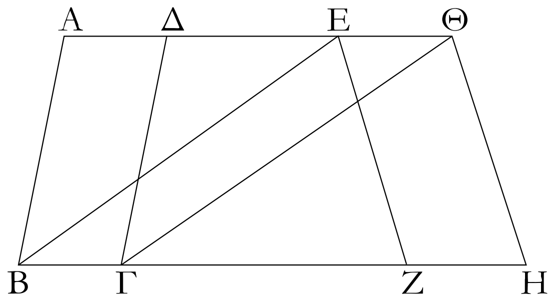
Τὰ παραλληλόγραμμα τὰ ἐπὶ ἴσων βάσεων ὄντα καὶ ἐν ταῖς αὐταῖς παραλλήλοις ἴσα ἀλλήλοις ἐστίν.

Ἔστω παραλληλόγραμμα τὰ ΑΒΓΔ, ΕΖΗΘ ἐπὶ ἴσων βάσεων ὄντα τῶν ΒΓ, ΖΗ καὶ ἐν ταῖς αὐταῖς παραλλήλοις ταῖς ΑΘ, ΒΗ· λέγω, ὅτι ἴσον ἐστὶ τὸ ΑΒΓΔ παραλληλόγραμμον τῷ ΕΖΗΘ.

Proposition 36

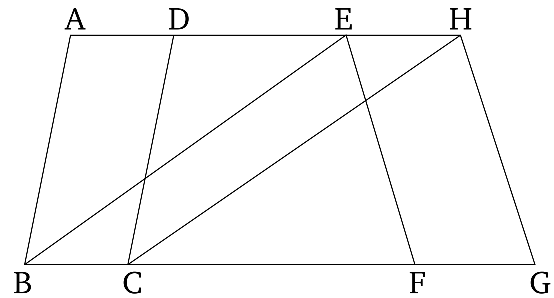
Parallelograms which are on equal bases and between the same parallels are equal to one another.

Let $ABCD$ and $EFGH$ be parallelograms which are on the equal bases BC and FG, and (are) between the same parallels AH and BG. I say that the parallelogram $ABCD$ is equal to $EFGH$.



Ἐπεζεύχθωσαν γὰρ αἱ ΒΕ, ΓΘ. καὶ ἐπεὶ ἴση ἐστὶν ἡ ΒΓ τῇ ΖΗ, ἀλλὰ ἡ ΖΗ τῇ ΕΘ ἐστιν ἴση, καὶ ἡ ΒΓ ἄρα τῇ ΕΘ ἐστιν ἴση. εἰσὶ δὲ καὶ παράλληλοι. καὶ ἐπιζευγνύουσιν αὐτὰς αἱ ΕΒ, ΘΓ· αἱ δὲ τὰς ἴσας τε καὶ παραλλήλους ἐπὶ τὰ αὐτὰ μέρη ἐπιζευγνύουσαι ἴσαι τε καὶ παράλληλοί εἰσι [καὶ αἱ ΕΒ, ΘΓ ἄρα ἴσας τέ εἰσι καὶ παράλληλοι]. παραλληλόγραμμον ἄρα ἐστὶ τὸ ΕΒΓΘ. καί ἐστιν ἴσον τῷ ΑΒΓΔ· βάσιν τε γὰρ αὐτῷ τὴν αὐτὴν ἔχει τὴν ΒΓ, καὶ ἐν ταῖς αὐταῖς παραλλήλοις ἐστὶν αὐτῷ ταῖς ΒΓ, ΑΘ. δὶα τὰ αὐτὰ δὴ καὶ τὸ ΕΖΗΘ τῷ αὐτῷ τῷ ΕΒΓΘ ἐστιν ἴσον· ὥστε καὶ τὸ ΑΒΓΔ παραλληλόγραμμον τῷ ΕΖΗΘ ἐστιν ἴσον.

Τὰ ἄρα παραλληλόγραμμα τὰ ἐπὶ ἴσων βάσεων ὄντα καὶ ἐν ταῖς αὐταῖς παραλλήλοις ἴσα ἀλλήλοις ἐστίν· ὅπερ ἔδει δεῖξαι.

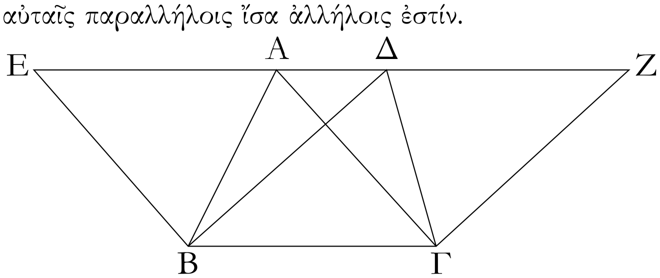


For let BE and CH have been joined. And since BC and FG are equal, but FG and EH are equal [Prop. 1.34], BC and EH are thus also equal. And they are also parallel, and EB and HC join them. But (straight-lines) joining equal and parallel (straight-lines) on the same sides are (themselves) equal and parallel [Prop. 1.33] [thus, EB and HC are also equal and parallel]. Thus, $EBCH$ is a parallelogram [Prop. 1.34], and is equal to $ABCD$. For it has the same base, BC, as ($ABCD$), and is between the same parallels, BC and AH, as ($ABCD$) [Prop. 1.35]. So, for the same (reasons), $EFGH$ is also equal to the same (parallelogram) $EBCH$ [Prop. 1.34]. So that the parallelogram $ABCD$ is also equal to $EFGH$.

Thus, parallelograms which are on equal bases and between the same parallels are equal to one another. (Which is) the very thing it was required to show.

λζ΄.

Τὰ τρίγωνα τὰ ἐπὶ τῆς αὐτῆς βάσεως ὄντα καὶ ἐν ταῖς αὐταῖς παραλλήλοις ἴσα ἀλλήλοις ἐστίν.

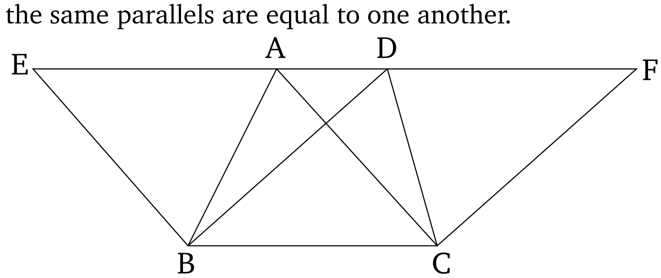


Ἔστω τρίγωνα τὰ ΑΒΓ, ΔΒΓ ἐπὶ τῆς αὐτῆς βάσεως τῆς ΒΓ καὶ ἐν ταῖς αὐταῖς παραλλήλοις ταῖς ΑΔ, ΒΓ· λέγω, ὅτι ἴσον ἐστὶ τὸ ΑΒΓ τρίγωνον τῷ ΔΒΓ τριγώνῳ.

Ἐκβεβλήσθω ἡ ΑΔ ἐφ᾽ ἑκάτερα τὰ μέρη ἐπὶ τὰ Ε, Ζ, καὶ διὰ μὲν τοῦ Β τῇ ΓΑ παράλληλος ἤχθω ἡ ΒΕ, δὶα δὲ τοῦ Γ τῇ ΒΔ παράλληλος ἤχθω ἡ ΓΖ. παραλληλόγραμμον ἄρα ἐστὶν ἑκάτερον τῶν ΕΒΓΑ, ΔΒΓΖ· καί εἰσιν ἴσα· ἐπί τε γὰρ τῆς αὐτῆς βάσεώς εἰσι τῆς ΒΓ καὶ ἐν ταῖς αὐταῖς παραλλήλοις ταῖς ΒΓ, ΕΖ· καί ἐστι τοῦ μὲν ΕΒΓΑ παραλληλογράμμου ἥμισυ τὸ ΑΒΓ τρίγωνον· ἡ γὰρ ΑΒ διάμετρος αὐτὸ δίχα τέμνει· τοῦ δὲ ΔΒΓΖ παραλληλογράμμου ἥμισυ τὸ ΔΒΓ τρίγωνον· ἡ γὰρ ΔΓ

Proposition 37

Triangles which are on the same base and between the same parallels are equal to one another.



Let ABC and DBC be triangles on the same base BC, and between the same parallels AD and BC. I say that triangle ABC is equal to triangle DBC.

Let AD have been produced in each direction to E and F, and let the (straight-line) BE have been drawn through B parallel to CA [Prop. 1.31], and let the (straight-line) CF have been drawn through C parallel to BD [Prop. 1.31]. Thus, $EBCA$ and $DBCF$ are both parallelograms, and are equal. For they are on the same base BC, and between the same parallels BC and EF [Prop. 1.35]. And the triangle ABC is half of the parallelogram $EBCA$. For the diagonal AB cuts the latter in διάμετρος αὐτὸ δίχα τέμνει. [τὰ δὲ τῶν ἴσων ἡμίση ἴσα ἀλλήλοις ἐστίν]. ἴσον ἄρα ἐστὶ τὸ ΑΒΓ τρίγωνον τῷ ΔΒΓ τριγώνῳ.

Τὰ ἄρα τρίγωνα τὰ ἐπὶ τῆς αὐτῆς βάσεως ὄντα καὶ ἐν ταῖς αὐταῖς παραλλήλοις ἴσα ἀλλήλοις ἐστίν· ὅπερ ἔδει δεῖξαι.

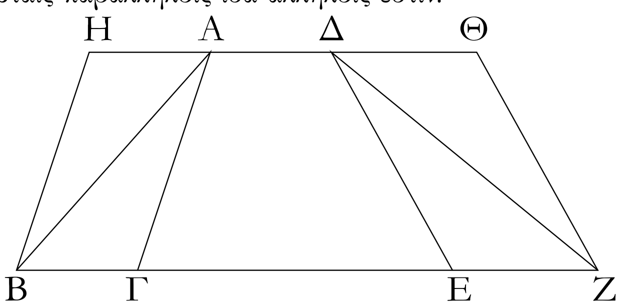
half [Prop. 1.34]. And the triangle DBC (is) half of the parallelogram $DBCF$. For the diagonal DC cuts the latter in half [Prop. 1.34]. [And the halves of equal things are equal to one another.]† Thus, triangle ABC is equal to triangle DBC.

Thus, triangles which are on the same base and between the same parallels are equal to one another. (Which is) the very thing it was required to show.

† This is an additional common notion.

λη΄.

Τὰ τρίγωνα τὰ ἐπὶ ἴσων βάσεων ὄντα καὶ ἐν ταῖς αὐταῖς παραλλήλοις ἴσα ἀλλήλοις ἐστίν.



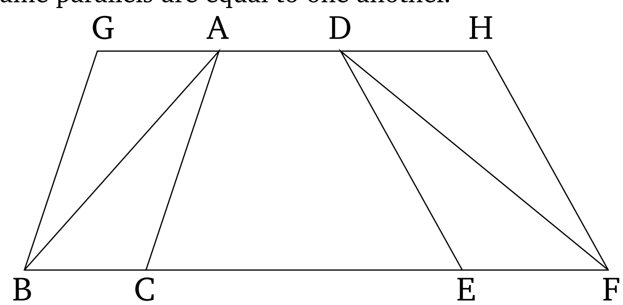
Ἔστω τρίγωνα τὰ ΑΒΓ, ΔΕΖ ἐπὶ ἴσων βάσεων τῶν ΒΓ, ΕΖ καὶ ἐν ταῖς αὐταῖς παραλλήλοις ταῖς ΒΖ, ΑΔ· λέγω, ὅτι ἴσον ἐστὶ τὸ ΑΒΓ τρίγωνον τῷ ΔΕΖ τριγώνῳ.

Ἐκβεβλήσθω γὰρ ἡ ΑΔ ἐφ᾽ ἑκάτερα τὰ μέρη ἐπὶ τὰ Η, Θ, καὶ διὰ μὲν τοῦ Β τῇ ΓΑ παράλληλος ἤχθω ἡ ΒΗ, δὶα δὲ τοῦ Ζ τῇ ΔΕ παράλληλος ἤχθω ἡ ΖΘ. παραλληλόγραμμον ἄρα ἐστὶν ἑκάτερον τῶν ΗΒΓΑ, ΔΕΖΘ· καὶ ἴσον τὸ ΗΒΓΑ τῷ ΔΕΖΘ· ἐπί τε γὰρ ἴσων βάσεών εἰσι τῶν ΒΓ, ΕΖ καὶ ἐν ταῖς αὐταῖς παραλλήλοις ταῖς ΒΖ, ΗΘ· καί΄ ἐστι τοῦ μὲν ΗΒΓΑ παραλληλογράμμου ἥμισυ τὸ ΑΒΓ τρίγωνον. ἡ γὰρ ΑΒ διάμετρος αὐτὸ δίχα τέμνει· τοῦ δὲ ΔΕΖΘ παραλληλογράμμου ἥμισυ τὸ ΖΕΔ τρίγωνον· ἡ γὰρ ΔΖ δίαμετρος αὐτὸ δίχα τέμνει [τὰ δὲ τῶν ἴσων ἡμίση ἴσα ἀλλήλοις ἐστίν]. ἴσον ἄρα ἐστὶ τὸ ΑΒΓ τρίγωνον τῷ ΔΕΖ τριγώνῳ.

Τὰ ἄρα τρίγωνα τὰ ἐπὶ ἴσων βάσεων ὄντα καὶ ἐν ταῖς αὐταῖς παραλλήλοις ἴσα ἀλλήλοις ἐστίν· ὅπερ ἔδει δεῖξαι.

Proposition 38

Triangles which are on equal bases and between the same parallels are equal to one another.



Let ABC and DEF be triangles on the equal bases BC and EF, and between the same parallels BF and AD. I say that triangle ABC is equal to triangle DEF.

For let AD have been produced in each direction to G and H, and let the (straight-line) BG have been drawn through B parallel to CA [Prop. 1.31], and let the (straight-line) FH have been drawn through F parallel to DE [Prop. 1.31]. Thus, $GBCA$ and $DEFH$ are each parallelograms. And $GBCA$ is equal to $DEFH$. For they are on the equal bases BC and EF, and between the same parallels BF and GH [Prop. 1.36]. And triangle ABC is half of the parallelogram $GBCA$. For the diagonal AB cuts the latter in half [Prop. 1.34]. And triangle FED (is) half of parallelogram $DEFH$. For the diagonal DF cuts the latter in half. [And the halves of equal things are equal to one another]. Thus, triangle ABC is equal to triangle DEF.

Thus, triangles which are on equal bases and between the same parallels are equal to one another. (Which is) the very thing it was required to show.

λθ΄.

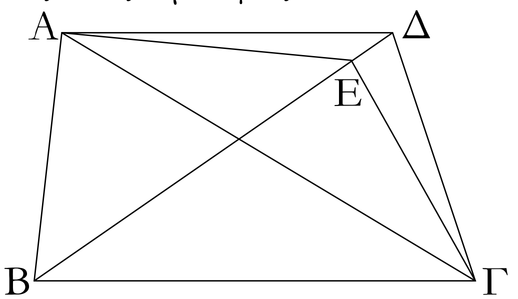
Τὰ ἴσα τρίγωνα τὰ ἐπὶ τῆς αὐτῆς βάσεως ὄντα καὶ ἐπὶ τὰ αὐτὰ μέρη καὶ ἐν ταῖς αὐταῖς παραλλήλοις ἐστίν.

Ἔστω ἴσα τρίγωνα τὰ ΑΒΓ, ΔΒΓ ἐπὶ τῆς αὐτῆς βάσεως ὄντα καὶ ἐπὶ τὰ αὐτὰ μέρη τῆς ΒΓ· λέγω, ὅτι

Proposition 39

Equal triangles which are on the same base, and on the same side, are also between the same parallels.

Let ABC and DBC be equal triangles which are on the same base BC, and on the same side. I say that they καὶ ἐν ταῖς αὐταῖς παραλλήλοις ἐστίν.

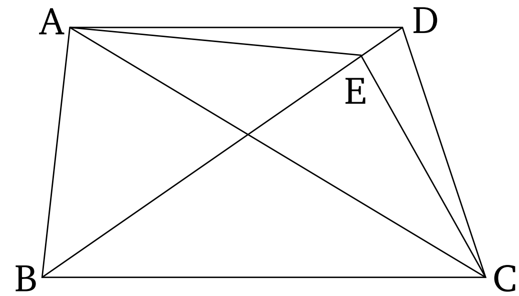


Ἐπεζεύχθω γὰρ ἡ ΑΔ· λέγω, ὅτι παράλληλός ἐστιν ἡ ΑΔ τῇ ΒΓ.

Εἰ γὰρ μή, ἤχθω διὰ τοῦ Α σημείου τῇ ΒΓ εὐθείᾳ παράλληλος ἡ ΑΕ, καὶ ἐπεζεύχθω ἡ ΕΓ. ἴσον ἄρα ἐστὶ τὸ ΑΒΓ τρίγωνον τῷ ΕΒΓ τριγώνῳ· ἐπί τε γὰρ τῆς αὐτῆς βάσεώς ἐστιν αὐτῷ τῆς ΒΓ καὶ ἐν ταῖς αὐταῖς παραλλήλοις. ἀλλὰ τὸ ΑΒΓ τῷ ΔΒΓ ἐστιν ἴσον· καὶ τὸ ΔΒΓ ἄρα τῷ ΕΒΓ ἴσον ἐστὶ τὸ μεῖζον τῷ ἐλάσσονι· ὅπερ ἐστὶν ἀδύνατον· οὐκ ἄρα παράλληλός ἐστιν ἡ ΑΕ τῇ ΒΓ. ὁμοίως δὴ δείξομεν, ὅτι οὐδ᾽ ἄλλη τις πλὴν τῆς ΑΔ· ἡ ΑΔ ἄρα τῇ ΒΓ ἐστι παράλληλος.

Τὰ ἄρα ἴσα τρίγωνα τὰ ἐπὶ τῆς αὐτῆς βάσεως ὄντα καὶ ἐπὶ τὰ αὐτὰ μέρη καὶ ἐν ταῖς αὐταῖς παραλλήλοις ἐστίν· ὅπερ ἔδει δεῖξαι.

are also between the same parallels.



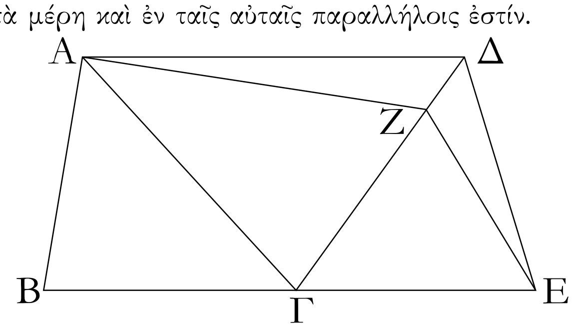
For let AD have been joined. I say that AD and AC are parallel.

For, if not, let AE have been drawn through point A parallel to the straight-line BC [Prop. 1.31], and let EC have been joined. Thus, triangle ABC is equal to triangle EBC. For it is on the same base as it, BC, and between the same parallels [Prop. 1.37]. But ABC is equal to DBC. Thus, DBC is also equal to EBC, the greater to the lesser. The very thing is impossible. Thus, AE is not parallel to BC. Similarly, we can show that neither (is) any other (straight-line) than AD. Thus, AD is parallel to BC.

Thus, equal triangles which are on the same base, and on the same side, are also between the same parallels. (Which is) the very thing it was required to show.

μ΄.

Τὰ ἴσα τρίγωνα τὰ ἐπὶ ἴσων βάσεων ὄντα καὶ ἐπὶ τὰ αὐτὰ μέρη καὶ ἐν ταῖς αὐταῖς παραλλήλοις ἐστίν.



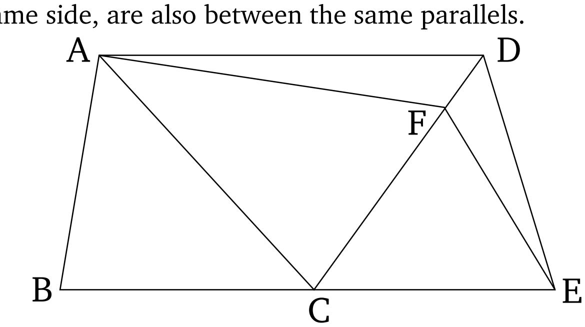
Ἔστω ἴσα τρίγωνα τὰ ΑΒΓ, ΓΔΕ ἐπὶ ἴσων βάσεων τῶν ΒΓ, ΓΕ καὶ ἐπὶ τὰ αὐτὰ μέρη. λέγω, ὅτι καὶ ἐν ταῖς αὐταῖς παραλλήλοις ἐστίν.

Ἐπεζεύχθω γὰρ ἡ ΑΔ· λέγω, ὅτι παράλληλός ἐστιν ἡ ΑΔ τῇ ΒΕ.

Εἰ γὰρ μή, ἤχθω διὰ τοῦ Α τῇ ΒΕ παράλληλος ἡ ΑΖ, καὶ ἐπεζεύχθω ἡ ΖΕ. ἴσον ἄρα ἐστὶ τὸ ΑΒΓ τρίγωνον τῷ ΖΓΕ τριγώνῳ· ἐπί τε γὰρ ἴσων βάσεών εἰσι τῶν ΒΓ, ΓΕ καὶ ἐν ταῖς αὐταῖς παραλλήλοις ταῖς ΒΕ, ΑΖ. ἀλλὰ τὸ ΑΒΓ τρίγωνον ἴσον ἐστὶ τῷ ΔΓΕ [τριγώνῳ]· καὶ τὸ ΔΓΕ ἄρα [τρίγωνον] ἴσον ἐστὶ τῷ ΖΓΕ

Proposition 40†

Equal triangles which are on equal bases, and on the same side, are also between the same parallels.



Let ABC and CDE be equal triangles on the equal bases BC and CE (respectively), and on the same side. I say that they are also between the same parallels.

For let AD have been joined. I say that AD is parallel to BE.

For if not, let AF have been drawn through A parallel to BE [Prop. 1.31], and let FE have been joined. Thus, triangle ABC is equal to triangle FCE. For they are on equal bases, BC and CE, and between the same parallels, BE and AF [Prop. 1.38]. But, triangle ABC is equal to [triangle] DCE. Thus, [triangle] DCE is also equal to τριγώνῳ τὸ μεῖζον τῷ ἐλάσσονι· ὅπερ ἐστὶν ἀδύνατον· οὐκ ἄρα παράλληλος ἡ ΑΖ τῇ ΒΕ. ὁμοίως δὴ δείξομεν, ὅτι οὐδ᾿ ἄλλη τις πλὴν τῆς ΑΔ· ἡ ΑΔ ἄρα τῇ ΒΕ ἐστι παράλληλος.

Τὰ ἄρα ἴσα τρίγωνα τὰ ἐπὶ ἴσων βάσεων ὄντα καὶ ἐπὶ τὰ αὐτὰ μέρη καὶ ἐν ταῖς αὐταῖς παραλλήλοις ἐστίν· ὅπερ ἔδει δεῖξαι.

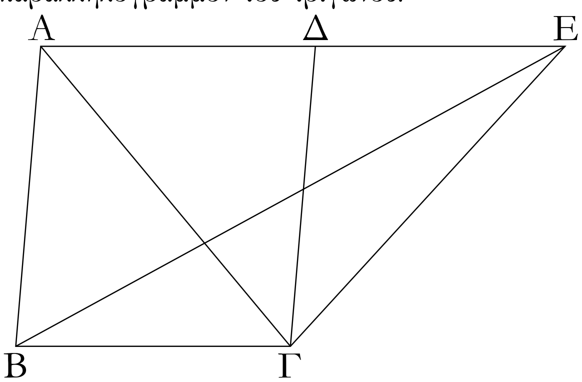
triangle FCE, the greater to the lesser. The very thing is impossible. Thus, AF is not parallel to BE. Similarly, we can show that neither (is) any other (straight-line) than AD. Thus, AD is parallel to BE.

Thus, equal triangles which are on equal bases, and on the same side, are also between the same parallels. (Which is) the very thing it was required to show.

† This whole proposition is regarded by Heiberg as a relatively early interpolation to the original text.

μα΄.

Ἐὰν παραλληλόγραμμον τριγώνῳ βάσιν τε ἔχῃ τὴν αὐτὴν καὶ ἐν ταῖς αὐταῖς παραλλήλοις ᾖ, διπλάσιόν ἐστί τὸ παραλληλόγραμμον τοῦ τριγώνου.



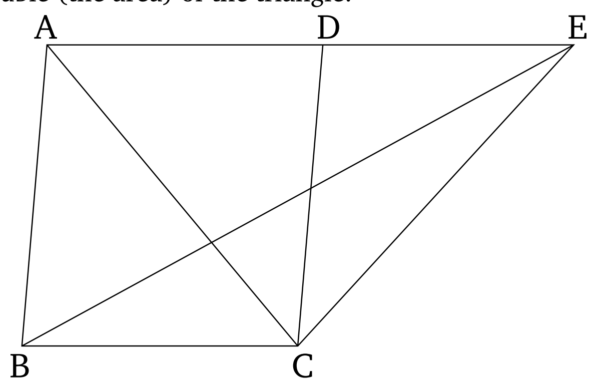
Παραλληλόγραμμον γὰρ τὸ ΑΒΓΔ τριγώνῳ τῷ ΕΒΓ βάσιν τε ἐχέτω τὴν αὐτὴν τὴν ΒΓ καὶ ἐν ταῖς αὐταῖς παραλλήλοις ἔστω ταῖς ΒΓ, ΑΕ· λέγω, ὅτι διπλάσιόν ἐστι τὸ ΑΒΓΔ παραλληλόγραμμον τοῦ ΒΕΓ τριγώνου.

Ἐπεζεύχθω γὰρ ἡ ΑΓ. ἴσον δή ἐστι τὸ ΑΒΓ τρίγωνον τῷ ΕΒΓ τριγώνῳ· ἐπί τε γὰρ τῆς αὐτῆς βάσεώς ἐστιν αὐτῷ τῆς ΒΓ καὶ ἐν ταῖς αὐταῖς παραλλήλοις ταῖς ΒΓ, ΑΕ. ἀλλὰ τὸ ΑΒΓΔ παραλληλόγραμμον διπλάσιόν ἔστι τοῦ ΑΒΓ τριγώνου· ἡ γὰρ ΑΓ διάμετρος αὐτὸ δίχα τέμνει· ὥστε τὸ ΑΒΓΔ παραλληλόγραμμον καὶ τοῦ ΕΒΓ τριγώνου ἐστὶ διπλάσιον.

Ἐὰν ἄρα παραλληλόγραμμον τριγώνῳ βάσιν τε ἔχῃ τὴν αὐτὴν καὶ ἐν ταῖς αὐταῖς παραλλήλοις ᾖ, διπλάσιόν ἐστί τὸ παραλληλόγραμμον τοῦ τριγώνου· ὅπερ ἔδει δεῖξαι.

Proposition 41

If a parallelogram has the same base as a triangle, and is between the same parallels, then the parallelogram is double (the area) of the triangle.



For let parallelogram $ABCD$ have the same base BC as triangle EBC, and let it be between the same parallels, BC and AE. I say that parallelogram $ABCD$ is double (the area) of triangle BEC.

For let AC have been joined. So triangle ABC is equal to triangle EBC. For it is on the same base, BC, as (EBC), and between the same parallels, BC and AE [Prop. 1.37]. But, parallelogram $ABCD$ is double (the area) of triangle ABC. For the diagonal AC cuts the former in half [Prop. 1.34]. So parallelogram $ABCD$ is also double (the area) of triangle EBC.

Thus, if a parallelogram has the same base as a triangle, and is between the same parallels, then the parallelogram is double (the area) of the triangle. (Which is) the very thing it was required to show.

μβ΄.

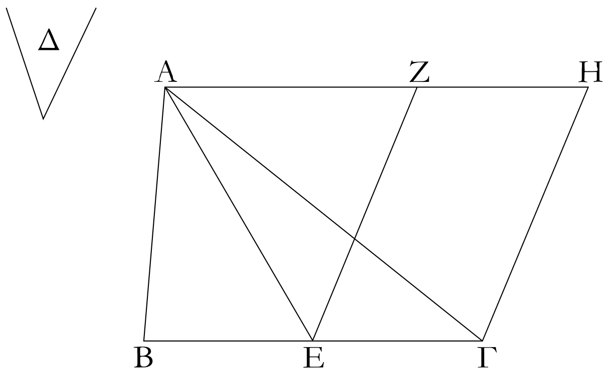
Τῷ δοθέντι τριγώνῳ ἴσον παραλληλόγραμμον συστήσασθαι ἐν τῇ δοθείσῃ γωνίᾳ εὐθυγράμμῳ.

Ἔστω τὸ μὲν δοθὲν τρίγωνον τὸ ΑΒΓ, ἡ δὲ δοθεῖσα γωνία εὐθύγραμμος ἡ Δ· δεῖ δὴ τῷ ΑΒΓ τριγώνῳ ἴσον παραλληλόγραμμον συστήσασθαι ἐν τῇ Δ γωνίᾳ εὐθυγράμμῳ.

Proposition 42

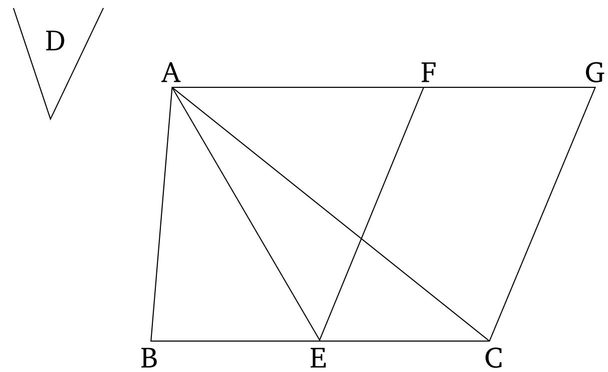
To construct a parallelogram equal to a given triangle in a given rectilinear angle.

Let ABC be the given triangle, and D the given rectilinear angle. So it is required to construct a parallelogram equal to triangle ABC in the rectilinear angle D.



Τετμήσθω ἡ ΒΓ δίχα κατὰ τὸ Ε, καὶ ἐπεζεύχθω ἡ ΑΕ, καὶ συνεστάτω πρὸς τῇ ΕΓ εὐθείᾳ καὶ τῷ πρὸς αὐτῃ σημείῳ τῷ Ε τῇ Δ γωνίᾳ ἴση ἡ ὑπὸ ΓΕΖ, καὶ διὰ μὲν τοῦ Α τῇ ΕΓ παράλληλος ἤχθω ἡ ΑΗ, διὰ δὲ τοῦ Γ τῇ ΕΖ παράλληλος ἤχθω ἡ ΓΗ· παραλληλόγραμμον ἄρα ἐστὶ τὸ ΖΕΓΗ. καὶ ἐπεὶ ἴση ἐστὶν ἡ ΒΕ τῇ ΕΓ, ἴσον ἐστὶ καὶ τὸ ΑΒΕ τρίγωνον τῷ ΑΕΓ τριγώνῳ· ἐπί τε γὰρ ἴσων βάσεών εἰσι τῶν ΒΕ, ΕΓ καὶ ἐν ταῖς αὐταῖς παραλλήλοις ταῖς ΒΓ, ΑΗ· διπλάσιον ἄρα ἐστὶ τὸ ΑΒΓ τρίγωνον τοῦ ΑΕΓ τριγώνου. ἔστι δὲ καὶ τὸ ΖΕΓΗ παραλληλόγραμμον διπλάσιον τοῦ ΑΕΓ τριγώνου· βάσιν τε γὰρ αὐτῷ τὴν αὐτὴν ἔχει καὶ ἐν ταῖς αὐταῖς ἐστιν αὐτῳ παραλλήλοις· ἴσον ἄρα ἐστὶ τὸ ΖΕΓΗ παραλληλόγραμμον τῷ ΑΒΓ τριγώνῳ. καὶ ἔχει τὴν ὑπὸ ΓΕΖ γωνίαν ἴσην τῇ δοθείσῃ τῇ Δ.

Τῷ ἄρα δοθέντι τριγώνῳ τῷ ΑΒΓ ἴσον παραλληλόγραμμον συνέσταται τὸ ΖΕΓΗ ἐν γωνίᾳ τῇ ὑπὸ ΓΕΖ, ἥτις ἐστὶν ἴση τῇ Δ· ὅπερ ἔδει ποιῆσαι.



Let BC have been cut in half at E [Prop. 1.10], and let AE have been joined. And let (angle) CEF, equal to angle D, have been constructed at the point E on the straight-line EC [Prop. 1.23]. And let AG have been drawn through A parallel to EC [Prop. 1.31], and let CG have been drawn through C parallel to EF [Prop. 1.31]. Thus, $FECG$ is a parallelogram. And since BE is equal to EC, triangle ABE is also equal to triangle AEC. For they are on the equal bases, BE and EC, and between the same parallels, BC and AG [Prop. 1.38]. Thus, triangle ABC is double (the area) of triangle AEC. And parallelogram $FECG$ is also double (the area) of triangle AEC. For it has the same base as (AEC), and is between the same parallels as (AEC) [Prop. 1.41]. Thus, parallelogram $FECG$ is equal to triangle ABC. ($FECG$) also has the angle CEF equal to the given (angle) D.

Thus, parallelogram $FECG$, equal to the given triangle ABC, has been constructed in the angle CEF, which is equal to D. (Which is) the very thing it was required to do.

μγ΄.

Παντὸς παραλληλογράμμου τῶν περὶ τὴν διάμετρον παραλληλογράμμων τὰ παραπληρώματα ἴσα ἀλλήλοις ἐστίν.

Ἔστω παραλληλόγραμμον τὸ ΑΒΓΔ, διάμετρος δὲ αὐτοῦ ἡ ΑΓ, περὶ δὲ τὴν ΑΓ παραλληλόγραμμα μὲν ἔστω τὰ ΕΘ, ΖΗ, τὰ δὲ λεγόμενα παραπληρώματα τὰ ΒΚ, ΚΔ· λέγω, ὅτι ἴσον ἐστὶ τὸ ΒΚ παραπλήρωμα τῷ ΚΔ παραπληρώματι.

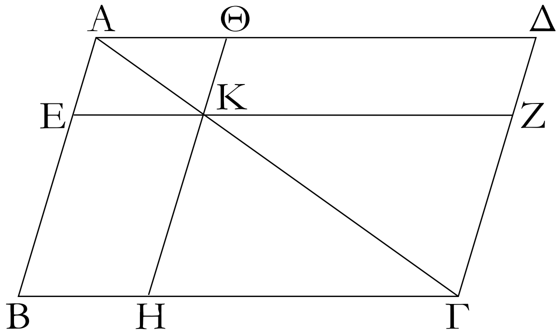
Ἐπεὶ γὰρ παραλληλόγραμμόν ἐστι τὸ ΑΒΓΔ, διάμετρος δὲ αὐτοῦ ἡ ΑΓ, ἴσον ἐστὶ τὸ ΑΒΓ τρίγωνον τῷ ΑΓΔ τριγώνῳ. πάλιν, ἐπεὶ παραλληλόγραμμόν ἐστι τὸ ΕΘ, διάμετρος δὲ αὐτοῦ ἐστιν ἡ ΑΚ, ἴσον ἐστὶ τὸ ΑΕΚ τρίγωνον τῷ ΑΘΚ τριγώνῳ. διὰ τὰ αὐτὰ δὴ καὶ τὸ ΚΖΓ τρίγωνον τῷ ΚΗΓ ἐστιν ἴσον. ἐπεὶ οὖν τὸ μὲν ΑΕΚ τρίγωνον τῷ ΑΘΚ τριγώνῳ ἐστὶν ἴσον, τὸ δὲ ΚΖΓ τῷ ΚΗΓ, τὸ ΑΕΚ τρίγωνον μετὰ τοῦ ΚΗΓ ἴσον ἐστὶ τῷ ΑΘΚ τριγώνῳ μετὰ τοῦ ΚΖΓ· ἔστι δὲ καὶ ὅλον

Proposition 43

For any parallelogram, the complements of the parallelograms about the diagonal are equal to one another.

Let $ABCD$ be a parallelogram, and AC its diagonal. And let EH and FG be the parallelograms about AC, and BK and KD the so-called complements (about AC). I say that the complement BK is equal to the complement KD.

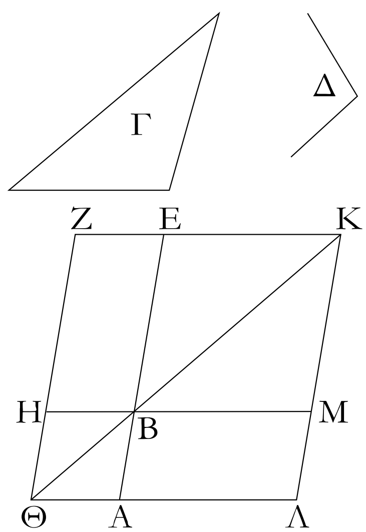
For since $ABCD$ is a parallelogram, and AC its diagonal, triangle ABC is equal to triangle ACD [Prop. 1.34]. Again, since EH is a parallelogram, and AK is its diagonal, triangle AEK is equal to triangle AHK [Prop. 1.34]. So, for the same (reasons), triangle KFC is also equal to (triangle) KGC. Therefore, since triangle AEK is equal to triangle AHK, and KFC to KGC, triangle AEK plus KGC is equal to triangle AHK plus KFC. And the whole triangle ABC is also equal to the whole (triangle) ADC. Thus, the remaining complement BK is equal to τὸ ΑΒΓ τρίγωνον ὅλῳ τῷ ΑΔΓ ἴσον· λοιπὸν ἄρα τὸ ΒΚ παραπλήρωμα λοιπῷ τῷ ΚΔ παραπληρώματί ἐστιν ἴσον.



Παντὸς ἄρα παραλληλογράμμου χωρίου τῶν περὶ τὴν διάμετρον παραλληλογράμμων τὰ παραπληρώματα ἴσα ἀλλήλοις ἐστίν· ὅπερ ἔδει δεῖξαι.

μδ´.

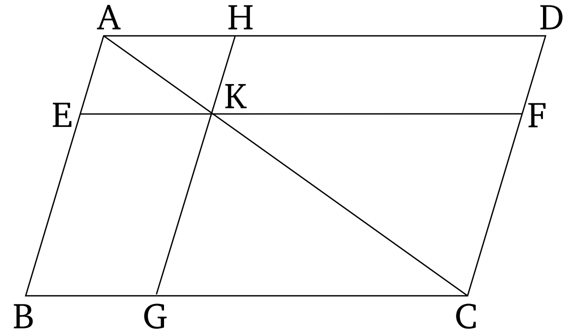
Παρὰ τὴν δοθεῖσαν εὐθεῖαν τῷ δοθέντι τριγώνῳ ἴσον παραλληλόγραμμον παραβαλεῖν ἐν τῇ δοθείσῃ γωνίᾳ εὐθυγράμμῳ.



Ἔστω ἡ μὲν δοθεῖσα εὐθεῖα ἡ ΑΒ, τὸ δὲ δοθὲν τρίγωνον τὸ Γ, ἡ δὲ δοθεῖσα γωνία εὐθύγραμμος ἡ Δ· δεῖ δὴ παρὰ τὴν δοθεῖσαν εὐθεῖαν τὴν ΑΒ τῷ δοθέντι τριγώνῳ τῷ Γ ἴσον παραλληλόγραμμον παραβαλείν ἐν ἴσῃ τῇ Δ γωνίᾳ.

Συνεστάτω τῷ Γ τριγώνῳ ἴσον παραλληλόγραμμον τὸ ΒΕΖΗ ἐν γωνίᾳ τῇ ὑπὸ ΕΒΗ, ἥ ἐστιν ἴση τῇ Δ· καὶ κείσθω ὥστε ἐπ᾽ εὐθείας εἶναι τὴν ΒΕ τῇ ΑΒ, καὶ διήχθω ἡ ΖΗ ἐπὶ τὸ Θ, καὶ διὰ τοῦ Α ὁποτέρᾳ τῶν ΒΗ, ΕΖ παράλληλος ἤχθω ἡ ΑΘ, καὶ ἐπεζεύχθω ἡ ΘΒ. καὶ ἐπεὶ εἰς παραλλήλους τὰς ΑΘ, ΕΖ εὐθεῖα ἐνέπεσεν ἡ ΘΖ, αἱ ἄρα ὑπὸ ΑΘΖ, ΘΖΕ γωνίαι δυσὶν

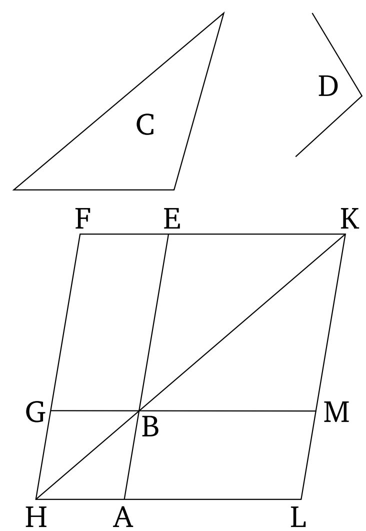
the remaining complement KD.



Thus, for any parallelogramic figure, the complements of the parallelograms about the diagonal are equal to one another. (Which is) the very thing it was required to show.

Proposition 44

To apply a parallelogram equal to a given triangle to a given straight-line in a given rectilinear angle.



Let AB be the given straight-line, C the given triangle, and D the given rectilinear angle. So it is required to apply a parallelogram equal to the given triangle C to the given straight-line AB in an angle equal to D.

Let the parallelogram $BEFG$, equal to the triangle C, have been constructed in the angle EBG, which is equal to D [Prop. 1.42]. And let it have been placed so that BE is straight-on to AB.† And let FG have been drawn through to H, and let AH have been drawn through A parallel to either of BG or EF [Prop. 1.31], and let HB have been joined. And since the straight-line HF falls across the parallel-lines AH and EF, the (sum of the) ὀρθαῖς εἰσιν ἴσαι. αἱ ἄρα ὑπὸ ΒΘΗ, ΗΖΕ δύο ὀρθῶν ἐλάσσονές εἰσιν· αἱ δὲ ἀπὸ ἐλασσόνων ἢ δύο ὀρθῶν εἰς ἄπειρον ἐκβαλλόμεναι συμπίπτουσιν· αἱ ΘΒ, ΖΕ ἄρα ἐκβαλλόμεναι συμπεσοῦνται. ἐκβεβλήσθωσαν καὶ συμπιπτέτωσαν κατὰ τὸ Κ, καὶ διὰ τοῦ Κ σημείου ὁποτέρᾳ τῶν ΕΑ, ΖΘ παράλληλος ἤχθω ἡ ΚΛ, καὶ ἐκβεβλήσθωσαν αἱ ΘΑ, ΗΒ ἐπὶ τὰ Λ, Μ σημεῖα. παραλληλόγραμμον ἄρα ἐστὶ τὸ ΘΛΚΖ, διάμετρος δὲ αὐτοῦ ἡ ΘΚ, περὶ δὲ τὴν ΘΚ παραλληλόγραμμα μὲν τὰ ΑΗ, ΜΕ, τὰ δὲ λεγόμενα παραπληρώματα τὰ ΛΒ, ΒΖ· ἴσον ἄρα ἐστὶ τὸ ΛΒ τῷ ΒΖ. ἀλλὰ τὸ ΒΖ τῷ Γ τριγώνῳ ἐστὶν ἴσον· καὶ τὸ ΛΒ ἄρα τῷ Γ ἐστιν ἴσον. καὶ ἐπεὶ ἴση ἐστὶν ἡ ὑπὸ ΗΒΕ γωνία τῇ ὑπὸ ΑΒΜ, ἀλλὰ ἡ ὑπὸ ΗΒΕ τῇ Δ ἐστιν ἴση, καὶ ἡ ὑπὸ ΑΒΜ ἄρα τῇ Δ γωνίᾳ ἐστὶν ἴση.

Παρὰ τὴν δοθεῖσαν ἄρα εὐθεῖαν τὴν ΑΒ τῷ δοθέντι τριγώνῳ τῷ Γ ἴσον παραλληλόγραμμον παραβέβληται τὸ ΛΒ ἐν γωνίᾳ τῇ ὑπὸ ΑΒΜ, ἥ ἐστιν ἴση τῇ Δ· ὅπερ ἔδει ποιῆσαι.

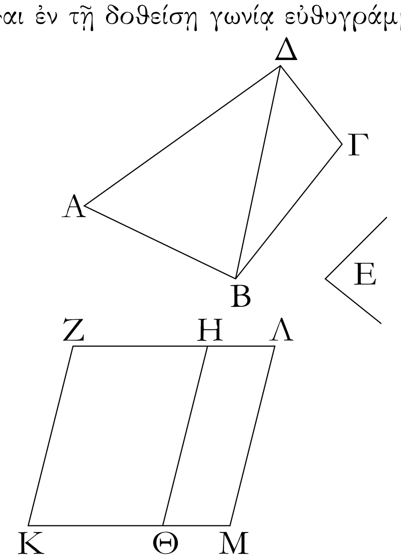
angles AHF and HFE is thus equal to two right-angles [Prop. 1.29]. Thus, (the sum of) BHG and GFE is less than two right-angles. And (straight-lines) produced to infinity from (internal angles whose sum is) less than two right-angles meet together [Post. 5]. Thus, being produced, HB and FE will meet together. Let them have been produced, and let them meet together at K. And let KL have been drawn through point K parallel to either of EA or FH [Prop. 1.31]. And let HA and GB have been produced to points L and M (respectively). Thus, $HLKF$ is a parallelogram, and HK its diagonal. And AG and ME (are) parallelograms, and LB and BF the so-called complements, about HK. Thus, LB is equal to BF [Prop. 1.43]. But, BF is equal to triangle C. Thus, LB is also equal to C. Also, since angle GBE is equal to ABM [Prop. 1.15], but GBE is equal to D, ABM is thus also equal to angle D.

Thus, the parallelogram LB, equal to the given triangle C, has been applied to the given straight-line AB in the angle ABM, which is equal to D. (Which is) the very thing it was required to do.

† This can be achieved using Props. 1.3, 1.23, and 1.31.

με´.

Τῷ δοθέντι εὐθυγράμμῳ ἴσον παραλληλόγραμμον συστήσασθαι ἐν τῇ δοθείσῃ γωνίᾳ εὐθυγράμμῳ.

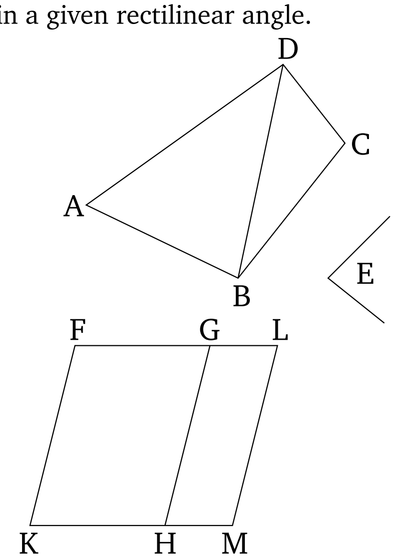


Ἔστω τὸ μὲν δοθὲν εὐθύγραμμον τὸ ΑΒΓΔ, ἡ δὲ δοθεῖσα γωνία εὐθύγραμμος ἡ Ε· δεῖ δὴ τῷ ΑΒΓΔ εὐθυγράμμῳ ἴσον παραλληλόγραμμον συστήσασθαι ἐν τῇ δοθείσῃ γωνίᾳ τῇ Ε.

Ἐπεζεύχθω ἡ ΔΒ, καὶ συνεστάτω τῷ ΑΒΔ τριγώνῳ ἴσον παραλληλόγραμμον τὸ ΖΘ ἐν τῇ ὑπὸ ΘΚΖ γωνίᾳ, ἥ ἐστιν ἴση τῇ Ε· καὶ παραβεβλήσθω παρὰ τὴν ΗΘ

Proposition 45

To construct a parallelogram equal to a given rectilinear figure in a given rectilinear angle.



Let $ABCD$ be the given rectilinear figure,† and E the given rectilinear angle. So it is required to construct a parallelogram equal to the rectilinear figure $ABCD$ in the given angle E.

Let DB have been joined, and let the parallelogram FH, equal to the triangle ABD, have been constructed in the angle HKF, which is equal to E [Prop. 1.42]. And let εὐθεῖαν τῷ ΔΒΓ τριγώνῳ ἴσον παραλληλόγραμμον τὸ ΗΜ ἐν τῇ ὑπὸ ΗΘΜ γωνίᾳ, ἥ ἐστιν ἴση τῇ Ε. καὶ ἐπεὶ ἡ Ε γωνία ἑκατέρᾳ τῶν ὑπὸ ΘΚΖ, ΗΘΜ ἐστιν ἴση, καὶ ἡ ὑπὸ ΘΚΖ ἄρα τῇ ὑπὸ ΗΘΜ ἐστιν ἴση. κοινὴ προσκείσθω ἡ ὑπὸ ΚΘΗ· αἱ ἄρα ὑπὸ ΖΚΘ, ΚΘΗ ταῖς ὑπὸ ΚΘΗ, ΗΘΜ ἴσαι εἰσίν. ἀλλ᾽ αἱ ὑπὸ ΖΚΘ, ΚΘΗ δυσὶν ὀρθαῖς ἴσαι εἰσίν· καὶ αἱ ὑπὸ ΚΘΗ, ΗΘΜ ἄρα δύο ὀρθαῖς ἴσας εἰσίν. πρὸς δή τινι εὐθείᾳ τῇ ΗΘ καὶ τῷ πρὸς αὐτῇ σημείῳ τῷ Θ δύο εὐθεῖαι αἱ ΚΘ, ΘΜ μὴ ἐπὶ τὰ αὐτὰ μέρη κείμεναι τὰς ἐφεξῆς γωνίας δύο ὀρθαῖς ἴσας ποιοῦσιν· ἐπ᾽ εὐθείας ἄρα ἐστὶν ἡ ΚΘ τῇ ΘΜ· καὶ ἐπεὶ εἰς παραλλήλους τὰς ΚΜ, ΖΗ εὐθεῖα ἐνέπεσεν ἡ ΘΗ, αἱ ἐναλλὰξ γωνίαι αἱ ὑπὸ ΜΘΗ, ΘΗΖ ἴσαι ἀλλήλαις εἰσίν. κοινὴ προσκείσθω ἡ ὑπὸ ΘΗΛ· αἱ ἄρα ὑπὸ ΜΘΗ, ΘΗΛ ταῖς ὑπὸ ΘΗΖ, ΘΗΛ ἴσαι εἰσιν. ἀλλ᾽ αἱ ὑπὸ ΜΘΗ, ΘΗΛ δύο ὀρθαῖς ἴσαι εἰσίν· καὶ αἱ ὑπὸ ΘΗΖ, ΘΗΛ ἄρα δύο ὀρθαῖς ἴσαι εἰσίν· ἐπ᾽ εὐθείας ἄρα ἐστὶν ἡ ΖΗ τῇ ΗΛ. καὶ ἐπεὶ ἡ ΖΚ τῇ ΘΗ ἴση τε καὶ παράλληλός ἐστιν, ἀλλὰ καὶ ἡ ΘΗ τῇ ΜΛ, καὶ ἡ ΚΖ ἄρα τῇ ΜΛ ἴση τε καὶ παράλληλός ἐστιν· καὶ ἐπιζευγνύουσιν αὐτὰς εὐθεῖαι αἱ ΚΜ, ΖΛ· καὶ αἱ ΚΜ, ΖΛ ἄρα ἴσαι τε καὶ παράλληλοί εἰσιν· παραλληλόγραμμον ἄρα ἐστὶ τὸ ΚΖΛΜ. καὶ ἐπεὶ ἴσον ἐστὶ τὸ μὲν ΑΒΔ τρίγωνον τῷ ΖΘ παραλληλογράμμῳ, τὸ δὲ ΔΒΓ τῷ ΗΜ, ὅλον ἄρα τὸ ΑΒΓΔ εὐθύγραμμον ὅλῳ τῷ ΚΖΛΜ παραλληλογράμμῳ ἐστὶν ἴσον.

Τῷ ἄρα δοθέντι εὐθυγράμμῳ τῷ ΑΒΓΔ ἴσον παραλληλόγραμμον συνέσταται τὸ ΚΖΛΜ ἐν γωνίᾳ τῇ ὑπὸ ΖΚΜ, ἥ ἐστιν ἴση τῇ δοθείσῃ τῇ Ε· ὅπερ ἔδει ποιῆσαι.

the parallelogram GM, equal to the triangle DBC, have been applied to the straight-line GH in the angle GHM, which is equal to E [Prop. 1.44]. And since angle E is equal to each of (angles) HKF and GHM, (angle) HKF is thus also equal to GHM. Let KHG have been added to both. Thus, (the sum of) FKH and KHG is equal to (the sum of) KHG and GHM. But, (the sum of) FKH and KHG is equal to two right-angles [Prop. 1.29]. Thus, (the sum of) KHG and GHM is also equal to two right-angles. So two straight-lines, KH and HM, not lying on the same side, make the (sum of the) adjacent angles equal to two right-angles at the point H on some straight-line GH. Thus, KH is straight-on to HM [Prop. 1.14]. And since the straight-line HG falls across the parallel-lines KM and FG, the alternate angles MHG and HGF are equal to one another [Prop. 1.29]. Let HGL have been added to both. Thus, (the sum of) MHG and HGL is equal to (the sum of) HGF and HGL. But, (the sum of) MHG and HGL is equal to two right-angles [Prop. 1.29]. Thus, (the sum of) HGF and HGL is also equal to two right-angles. Thus, FG is straight-on to GL [Prop. 1.14]. And since FK is equal and parallel to HG [Prop. 1.34], but also HG to ML [Prop. 1.34], KF is thus also equal and parallel to ML [Prop. 1.30]. And the straight-lines KM and FL join them. Thus, KM and FL are equal and parallel as well [Prop. 1.33]. Thus, $KFLM$ is a parallelogram. And since triangle ABD is equal to parallelogram FH, and DBC to GM, the whole rectilinear figure $ABCD$ is thus equal to the whole parallelogram $KFLM$.

Thus, the parallelogram $KFLM$, equal to the given rectilinear figure $ABCD$, has been constructed in the angle FKM, which is equal to the given (angle) E. (Which is) the very thing it was required to do.

† The proof is only given for a four-sided figure. However, the extension to many-sided figures is trivial.

μϛ΄.

Ἀπὸ τῆς δοθείσης εὐθείας τετράγωνον ἀναγράψαι.

Ἔστω ἡ δοθεῖσα εὐθεῖα ἡ ΑΒ· δεῖ δὴ ἀπὸ τῆς ΑΒ εὐθείας τετράγωνον ἀναγράψαι.

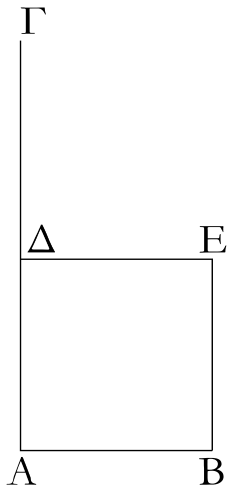
Ἤχθω τῇ ΑΒ εὐθείᾳ ἀπὸ τοῦ πρὸς αὐτῇ σημείου τοῦ Α πρὸς ὀρθὰς ἡ ΑΓ, καὶ κείσθω τῇ ΑΒ ἴση ἡ ΑΔ· καὶ διὰ μὲν τοῦ Δ σημείου τῇ ΑΒ παράλληλος ἤχθω ἡ ΔΕ, διὰ δὲ τοῦ Β σημείου τῇ ΑΔ παράλληλος ἤχθω ἡ ΒΕ. παραλληλόγραμμον ἄρα ἐστὶ τὸ ΑΔΕΒ· ἴση ἄρα ἐστὶν ἡ μὲν ΑΒ τῇ ΔΕ, ἡ δὲ ΑΔ τῇ ΒΕ. ἀλλὰ ἡ ΑΒ τῇ ΑΔ ἐστιν ἴση· αἱ τέσσαρες ἄρα αἱ ΒΑ, ΑΔ, ΔΕ, ΕΒ ἴσαι ἀλλήλαις εἰσίν· ἰσόπλευρον ἄρα ἐστὶ τὸ ΑΔΕΒ παραλληλόγραμμον. λέγω δή, ὅτι καὶ ὀρθογώνιον. ἐπεὶ γὰρ εἰς παραλλήλους τὰς ΑΒ, ΔΕ εὐθεῖα ἐνέπεσεν ἡ ΑΔ,

Proposition 46

To describe a square on a given straight-line.

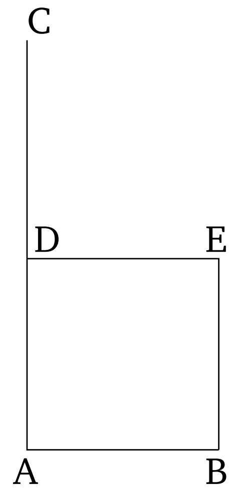
Let AB be the given straight-line. So it is required to describe a square on the straight-line AB.

Let AC have been drawn at right-angles to the straight-line AB from the point A on it [Prop. 1.11], and let AD have been made equal to AB [Prop. 1.3]. And let DE have been drawn through point D parallel to AB [Prop. 1.31], and let BE have been drawn through point B parallel to AD [Prop. 1.31]. Thus, $ADEB$ is a parallelogram. Thus, AB is equal to DE, and AD to BE [Prop. 1.34]. But, AB is equal to AD. Thus, the four (sides) BA, AD, DE, and EB are equal to one another. Thus, the parallelogram $ADEB$ is equilateral. So αἱ ἄρα ὑπὸ ΒΑΔ, ΑΔΕ γωνίαι δύο ὀρθαῖς ἴσαι εἰσίν. ὀρθὴ δὲ ἡ ὑπὸ ΒΑΔ· ὀρθὴ ἄρα καὶ ἡ ὑπὸ ΑΔΕ. τῶν δὲ παραλληλογράμμων χωρίων αἱ ἀπεναντίον πλευραί τε καὶ γωνίαι ἴσαι ἀλλήλαις εἰσίν· ὀρθὴ ἄρα καὶ ἑκατέρα τῶν ἀπεναντίον τῶν ὑπὸ ΑΒΕ, ΒΕΔ γωνιῶν· ὀρθογώνιον ἄρα ἐστὶ τὸ ΑΔΕΒ. ἐδείχθη δὲ καὶ ἰσόπλευρον.



Τετράγωνον ἄρα ἐστίν· καί ἐστιν ἀπὸ τῆς ΑΒ εὐθείας ἀναγεγραμμένον· ὅπερ ἔδει ποιῆσαι.

I say that (it is) also right-angled. For since the straight-line AD falls across the parallel-lines AB and DE, the (sum of the) angles BAD and ADE is equal to two right-angles [Prop. 1.29]. But BAD (is a) right-angle. Thus, ADE (is) also a right-angle. And for parallelogrammic figures, the opposite sides and angles are equal to one another [Prop. 1.34]. Thus, each of the opposite angles ABE and BED (are) also right-angles. Thus, $ADEB$ is right-angled. And it was also shown (to be) equilateral.



Thus, ($ADEB$) is a square [Def. 1.22]. And it is described on the straight-line AB. (Which is) the very thing it was required to do.

μζ΄.

Ἐν τοῖς ὀρθογωνίοις τριγώνοις τὸ ἀπὸ τῆς τὴν ὀρθὴν γωνίαν ὑποτεινούσης πλευρᾶς τετράγωνον ἴσον ἐστὶ τοῖς ἀπὸ τῶν τὴν ὀρθὴν γωνίαν περιεχουσῶν πλευρῶν τετραγώνοις.

Ἔστω τρίγωνον ὀρθογώνιον τὸ ΑΒΓ ὀρθὴν ἔχον τὴν ὑπὸ ΒΑΓ γωνίαν· λέγω, ὅτι τὸ ἀπὸ τῆς ΒΓ τετράγωνον ἴσον ἐστὶ τοῖς ἀπὸ τῶν ΒΑ, ΑΓ τετραγώνοις.

Ἀναγεγράφθω γὰρ ἀπὸ μὲν τῆς ΒΓ τετράγωνον τὸ ΒΔΕΓ, ἀπὸ δὲ τῶν ΒΑ, ΑΓ τὰ ΗΒ, ΘΓ, καὶ διὰ τοῦ Α ὁποτέρᾳ τῶν ΒΔ, ΓΕ παράλληλος ἤχθω ἡ ΑΛ· καὶ ἐπεζεύχθωσαν αἱ ΑΔ, ΖΓ. καὶ ἐπεὶ ὀρθή ἐστιν ἑκατέρα τῶν ὑπὸ ΒΑΓ, ΒΑΗ γωνιῶν, πρὸς δή τινι εὐθείᾳ τῇ ΒΑ καὶ τῷ πρὸς αὐτῇ σημείῳ τῷ Α δύο εὐθεῖαι αἱ ΑΓ, ΑΗ μὴ ἐπὶ τὰ αὐτὰ μέρη κείμεναι τὰς ἐφεξῆς γωνίας δυσὶν ὀρθαῖς ἴσας ποιοῦσιν· ἐπ᾽ εὐθείας ἄρα ἐστὶν ἡ ΓΑ τῇ ΑΗ. διὰ τὰ αὐτὰ δὴ καὶ ἡ ΒΑ τῇ ΑΘ ἐστιν ἐπ᾽ εὐθείας. καὶ ἐπεὶ ἴση ἐστὶν ἡ ὑπὸ ΔΒΓ γωνία τῇ ὑπὸ ΖΒΑ· ὀρθὴ γὰρ ἑκατέρα· κοινὴ προσκείσθω ἡ ὑπὸ ΑΒΓ· ὅλη ἄρα ἡ ὑπὸ ΔΒΑ ὅλη τῇ ὑπὸ ΖΒΓ ἐστιν ἴση. καὶ ἐπεὶ ἴση ἐστὶν ἡ μὲν ΔΒ τῇ ΒΓ, ἡ δὲ ΖΒ τῇ ΒΑ, δύο δὴ αἱ ΔΒ, ΒΑ δύο ταῖς ΖΒ, ΒΓ ἴσαι εἰσὶν ἑκατέρα ἑκατέρᾳ· καὶ γωνία

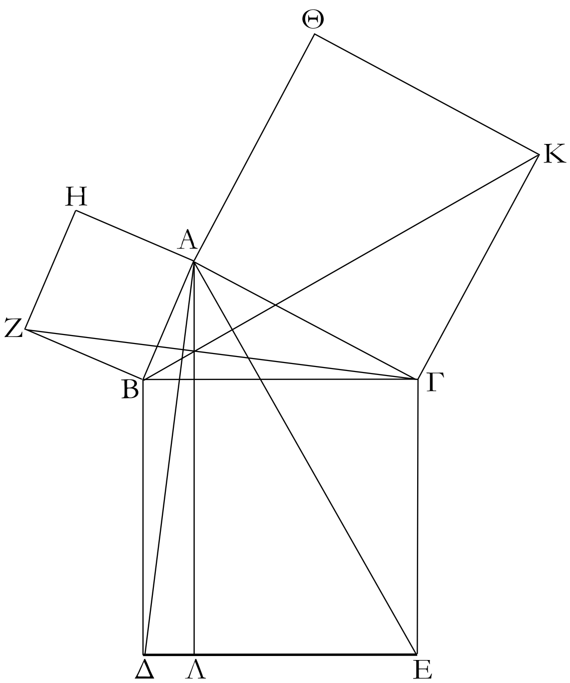
Proposition 47

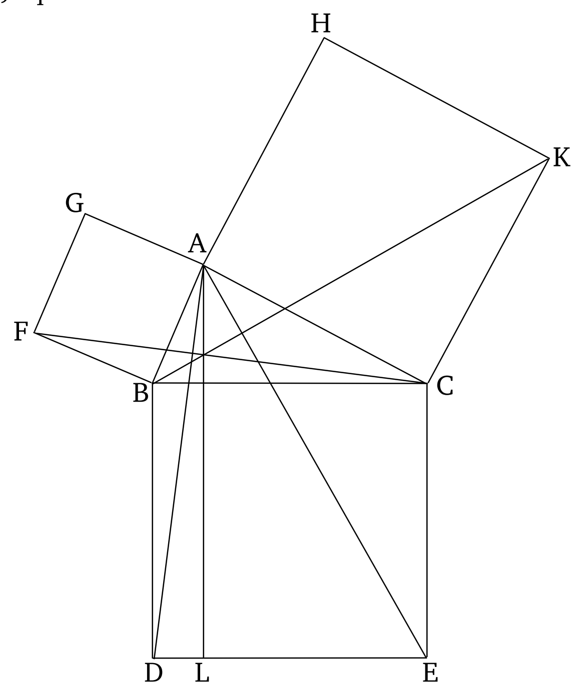
In a right-angled triangle, the square on the side subtending the right-angle is equal to the (sum of the) squares on the sides surrounding the right-angle.

Let ABC be a right-angled triangle having the right-angle BAC. I say that the square on BC is equal to the (sum of the) squares on BA and AC.

For let the square $BDEC$ have been described on BC, and (the squares) GB and HC on AB and AC (respectively) [Prop. 1.46]. And let AL have been drawn through point A parallel to either of BD or CE [Prop. 1.31]. And let AD and FC have been joined. And since angles BAC and BAG are each right-angles, then two straight-lines AC and AG, not lying on the same side, make the (sum of the) adjacent angles equal to two right-angles at the same point A on some straight-line BA . Thus, CA is straight-on to AG [Prop. 1.14]. So, for the same (reasons), BA is also straight-on to AH. And since angle DBC is equal to FBA, for (they are) both right-angles, let ABC have been added to both. Thus, the whole (angle) DBA is equal to the whole (angle) FBC. And since DB is equal to BC, and FB to BA, ἡ ὑπὸ ΔΒΑ γωνίᾳ τῇ ὑπὸ ΖΒΓ ἴση· βάσις ἄρα ἡ ΑΔ βάσει τῇ ΖΓ [ἐστιν] ἴση, καὶ τὸ ΑΒΔ τρίγωνον τῷ ΖΒΓ τριγώνῳ ἐστὶν ἴσον· καί [ἐστι] τοῦ μὲν ΑΒΔ τριγώνου διπλάσιον τὸ ΒΛ παραλληλόγραμμον· βάσιν τε γὰρ τὴν αὐτὴν ἔχουσι τὴν ΒΔ καὶ ἐν ταῖς αὐταῖς εἰσι παραλλήλοις ταῖς ΒΔ, ΑΛ· τοῦ δὲ ΖΒΓ τριγώνου διπλάσιον τὸ ΗΒ τετράγωνον· βάσιν τε γὰρ πάλιν τὴν αὐτὴν ἔχουσι τὴν ΖΒ καὶ ἐν ταῖς αὐταῖς εἰσι παραλλήλοις ταῖς ΖΒ, ΗΓ. [τὰ δὲ τῶν ἴσων διπλάσια ἴσα ἀλλήλοις ἐστίν·] ἴσον ἄρα ἐστὶ καὶ τὸ ΒΛ παραλληλόγραμμον τῷ ΗΒ τετραγώνῳ. ὁμοίως δὴ ἐπιζευγνυμένων τῶν ΑΕ, ΒΚ δειχθήσεται καὶ τὸ ΓΛ παραλληλόγραμμον ἴσον τῷ ΘΓ τετραγώνῳ· ὅλον ἄρα τὸ ΒΔΕΓ τετράγωνον δυσὶ τοῖς ΗΒ, ΘΓ τετραγώνοις ἴσον ἐστίν. καί ἐστι τὸ μὲν ΒΔΕΓ τετράγωνον ἀπὸ τῆς ΒΓ ἀναγραφέν, τὰ δὲ ΗΒ, ΘΓ ἀπὸ τῶν ΒΑ, ΑΓ. τὸ ἄρα ἀπὸ τῆς ΒΓ πλευρᾶς τετράγωνον ἴσον ἐστὶ τοῖς ἀπὸ τῶν ΒΑ, ΑΓ πλευρῶν τετραγώνοις.

the two (straight-lines) DB, BA are equal to the two (straight-lines) CB, BF,† respectively. And angle DBA (is) equal to angle FBC. Thus, the base AD [is] equal to the base FC, and the triangle ABD is equal to the triangle FBC [Prop. 1.4]. And parallelogram BL [is] double (the area) of triangle ABD. For they have the same base, BD, and are between the same parallels, BD and AL [Prop. 1.41]. And parallelogram GB is double (the area) of triangle FBC. For again they have the same base, FB, and are between the same parallels, FB and GC [Prop. 1.41]. [And the doubles of equal things are equal to one another.]‡ Thus, the parallelogram BL is also equal to the square GB. So, similarly, AE and BK being joined, the parallelogram CL can be shown (to be) equal to the square HC. Thus, the whole square $BDEC$ is equal to the (sum of the) two squares GB and HC. And the square $BDEC$ is described on BC, and the (squares) GB and HC on BA and AC (respectively). Thus, the square on the side BC is equal to the (sum of the) squares on the sides BA and AC.





Ἐν ἄρα τοῖς ὀρθογωνίοις τριγώνοις τὸ ἀπὸ τῆς τὴν ὀρθὴν γωνίαν ὑποτεινούσης πλευρᾶς τετράγωνον ἴσον ἐστὶ τοῖς ἀπὸ τῶν τὴν ὀρθὴν [γωνίαν] περιεχουσῶν πλευρῶν τετραγώνοις· ὅπερ ἔδει δεῖξαι.

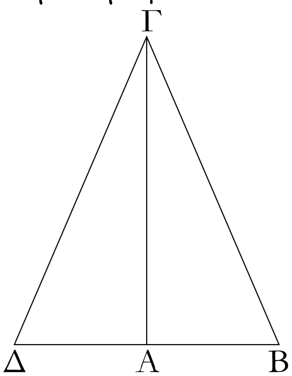
Thus, in a right-angled triangle, the square on the side subtending the right-angle is equal to the (sum of the) squares on the sides surrounding the right-[angle]. (Which is) the very thing it was required to show.

† The Greek text has "FB, BC", which is obviously a mistake.

‡ This is an additional common notion.

μη΄.

Ἐὰν τριγώνου τὸ ἀπὸ μιᾶς τῶν πλευρῶν τετράγωνον ἴσον ᾖ τοῖς ἀπὸ τῶν λοιπῶν τοῦ τριγώνου δύο πλευρῶν τετραγώνοις, ἡ περιεχομένη γωνία ὑπὸ τῶν λοιπῶν τοῦ τριγώνου δύο πλευρῶν ὀρθή ἐστιν.



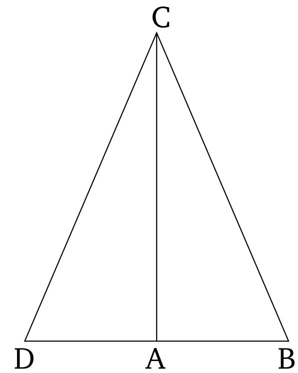
Τριγώνου γὰρ τοῦ ΑΒΓ τὸ ἀπὸ μιᾶς τῆς ΒΓ πλευρᾶς τετράγωνον ἴσον ἔστω τοῖς ἀπὸ τῶν ΒΑ, ΑΓ πλευρῶν τετραγώνοις· λέγω, ὅτι ὀρθή ἐστιν ἡ ὑπὸ ΒΑΓ γωνία.

Ἤχθω γὰρ ἀπὸ τοῦ Α σημείου τῇ ΑΓ εὐθείᾳ πρὸς ὀρθὰς ἡ ΑΔ καὶ κείσθω τῇ ΒΑ ἴση ἡ ΑΔ, καὶ ἐπεζεύχθω ἡ ΔΓ. ἐπεὶ ἴση ἐστὶν ἡ ΔΑ τῇ ΑΒ, ἴσον ἐστὶ καὶ τὸ ἀπὸ τῆς ΔΑ τετράγωνον τῷ ἀπὸ τῆς ΑΒ τετραγώνῳ. κοινὸν προσκείσθω τὸ ἀπὸ τῆς ΑΓ τετράγωνον· τὰ ἄρα ἀπὸ τῶν ΔΑ, ΑΓ τετράγωνα ἴσα ἐστὶ τοῖς ἀπὸ τῶν ΒΑ, ΑΓ τετραγώνοις. ἀλλὰ τοῖς μὲν ἀπὸ τῶν ΔΑ, ΑΓ ἴσον ἐστὶ τὸ ἀπὸ τῆς ΔΓ· ὀρθὴ γάρ ἐστιν ἡ ὑπὸ ΔΑΓ γωνία· τοῖς δὲ ἀπὸ τῶν ΒΑ, ΑΓ ἴσον ἐστὶ τὸ ἀπὸ τῆς ΒΓ· ὑπόκειται γάρ· τὸ ἄρα ἀπὸ τῆς ΔΓ τετράγωνον ἴσον ἐστὶ τῷ ἀπὸ τῆς ΒΓ τετραγώνῳ· ὥστε καὶ πλευρὰ ἡ ΔΓ τῇ ΒΓ ἐστιν ἴση· καὶ ἐπεὶ ἴση ἐστὶν ἡ ΔΑ τῇ ΑΒ, κοινὴ δὲ ἡ ΑΓ, δύο δὴ αἱ ΔΑ, ΑΓ δύο ταῖς ΒΑ, ΑΓ ἴσαι εἰσίν· καὶ βάσις ἡ ΔΓ βάσει τῇ ΒΓ ἴση· γωνία ἄρα ἡ ὑπὸ ΔΑΓ γωνίᾳ τῇ ὑπὸ ΒΑΓ [ἐστιν] ἴση. ὀρθὴ δὲ ἡ ὑπὸ ΔΑΓ· ὀρθὴ ἄρα καὶ ἡ ὑπὸ ΒΑΓ.

Ἐὰν ἀρὰ τριγώνου τὸ ἀπὸ μιᾶς τῶν πλευρῶν τετράγωνον ἴσον ᾖ τοῖς ἀπὸ τῶν λοιπῶν τοῦ τριγώνου δύο πλευρῶν τετραγώνοις, ἡ περιεχομένη γωνία ὑπὸ τῶν λοιπῶν τοῦ τριγώνου δύο πλευρῶν ὀρθή ἐστιν· ὅπερ ἔδει δεῖξαι.

Proposition 48

If the square on one of the sides of a triangle is equal to the (sum of the) squares on the remaining sides of the triangle then the angle contained by the remaining sides of the triangle is a right-angle.



For let the square on one of the sides, BC, of triangle ABC be equal to the (sum of the) squares on the sides BA and AC. I say that angle BAC is a right-angle.

For let AD have been drawn from point A at right-angles to the straight-line AC [Prop. 1.11], and let AD have been made equal to BA [Prop. 1.3], and let DC have been joined. Since DA is equal to AB, the square on DA is thus also equal to the square on AB.† Let the square on AC have been added to both. Thus, the (sum of the) squares on DA and AC is equal to the (sum of the) squares on BA and AC. But, the (sum of the squares) on DA and AC is equal to the (square) on DC. For angle DAC is a right-angle [Prop. 1.47]. But, the (sum of the squares) on BA and AC is equal to the (square) on BC. For (that) was assumed. Thus, the square on DC is equal to the square on BC. So DC is also equal to BC. And since DA is equal to AB, and AC (is) common, the two (straight-lines) DA, AC are equal to the two (straight-lines) BA, AC. And the base DC is equal to the base BC. Thus, angle DAC [is] equal to angle BAC [Prop. 1.8]. But DAC is a right-angle. Thus, BAC is also a right-angle.

Thus, if the square on one of the sides of a triangle is equal to the (sum of the) squares on the remaining sides of the triangle then the angle contained by the remaining sides of the triangle is a right-angle. (Which is) the very thing it was required to show.

† Here, use is made of the additional common notion that the squares of equal things are themselves equal. Later on, the inverse notion is used.

GREEK-ENGLISH LEXICON

ABBREVIATIONS: *act* - active; *adj* - adjective; *adv* - adverb; *conj* - conjunction; *fut* - future; *gen* - genitive; *imperat* - imperative; *impf* - imperfect; *ind* - indeclinable; *indic* - indicative; *intr* - intransitive; *mid* - middle; *neut* - neuter; *no* - noun; *par* - particle; *part* - participle; *pass* - passive; *perf* - perfect; *pre* - preposition; *pres* - present; *pro* - pronoun; *sg* - singular; *tr* - transitive; *vb* - verb.

ἄγω, ἄξω, ἤγαγον, -ῆχα, ἦγμαι, ἤχθην : *vb*, lead, draw (a line).

ἀδύνατος -ον : *adj*, impossible.

ἀεί : *adv*, always, for ever.

αἱρέω, αἱρήσω, ε[ἷ]λον, ᾕρηκα, ᾕρημαι, ᾑρέθην : *vb*, grasp.

ἀιτέω, αἰτήσω, ᾔτησα, ᾔτηκα, ᾔτημαι, ᾐτήθη : *vb*, postulate.

αἴτημα -ατος, τό : *no*, postulate.

ἀκόλουθος -ον : *adj*, analogous, consequent on, in conformity with.

ἄκρος -α -ον : *adj*, outermost, end, extreme.

ἀλλά : *conj*, but, otherwise.

ἄλογος -ον : *adj*, irrational.

ἅμα : *adv*, at once, at the same time, together.

ἀμβλυγώνιος -ον : *adj*, obtuse-angled; τὸ ἀμβλυγώνιον, *no*, obtuse angle.

ἀμβλύς -εῖα -ύ : *adj*, obtuse.

ἀμφότερος -α -ον : *pro*, both (of two).

ἀναγράφω : *vb*, describe (a figure); see γράφω.

ἀναλογία, ἡ : *no*, proportion, (geometric) progression.

ἀνάλογος -ον : *adj*, proportional.

ἀνάπαλιν : *adv*, inverse(ly).

αναπληρόω : *vb*, fill up.

ἀναστρέφω : *vb*, turn upside down, convert (ratio); see στρέφω.

ἀναστροφή, ἡ : *no*, turning upside down, conversion (of ratio).

ἀνθυφαιρέω : *vb*, take away in turn; see αἱρέω.

ἀνίστημι : *vb*, set up; see ἵστημι.

ἄνισος -ον : *adj*, unequal, uneven.

ἀντιπάσχω : *vb*, be reciprocally proportional; see πάσχω.

ἄξων -ονος, ὁ : *vb*, axis.

ἅπαξ : *adv*, once.

ἅπας, ἅπασα, ἅπαν : *adj*, quite all, the whole.

ἄπειρος -ον : *adj*, infinite.

ἀπεναντίον : *ind*, opposite.

ἀπέχω : *vb*, be far from, be away from; see ἔχω.

ἀπλατής -ές : *adj*, without breadth.

ἀπόδειξις -εως, ἡ : *no*, proof.

ἀποκαθίστημι : *vb*, re-establish, restore; see ἵστημι.

ἀπολαμβάνω : *vb*, take from, subtract from, cut off from; see λαμβάνω.

ἀπότμημα -ατος, τὸ : *no*, piece cut off, segment.

ἀποτομή, ἡ : *vb*, piece cut off, apotome.

ἅπτω, ἅψω, ἧψα, —, ἧμμαι, — : *vb*, touch, join, meet.

ἀπώτερος -α -ον : *adj*, further off.

ἄρα : *par*, thus, as it seems (inferential).

ἀριθμός, ὁ : *no*, number.

ἀρτιάκις : *adv*, an even number of times.

αρτιόπλευρος -ον : *adj*, having a even number of sides.

ἄρχω, ἄρξω, ἦρξα, ἦρχα, ἦργμαι, ἤρχθην : *vb*, rule; *mid.*, begin.

ἀσύμμετρος -ον : *adj*, incommensurable.

ἀσύμπτωτος -ον : *adj*, not touching, not meeting.

ἄρτιος -α -ον : *adj*, even, perfect.

ἄτμητος -ον : *adj*, uncut.

ἀτόπος -ον : *adj*, absurd, paradoxical.

αὐτόθεν : *adv*, immediately, obviously.

ἀφαίρεω : *vb*, take from, subtract from, cut off from; see αἱρέω.

ἁφή, ἡ : *no*, point of contact.

βάθος -εος, τό : *no*, depth, height.

βαίνω, -βήσομαι, -έβην, βέβηκα, —, — : *vb*, walk; *perf*, stand (of angle).

βάλλω, βαλῶ, ἔβαλον, βέβληκα, βέβλημαι, ἐβλήθην : *vb*, throw.

βάσις -εως, ἡ : *no*, base (of a triangle).

γάρ : *conj*, for (explanatory).

γί[γ]νομαι, γενήσομαι, ἐγενόμην, γέγονα, γεγένημαι, — : *vb*, happen, become.

γνώμων -ονος, ἡ : *no*, gnomon.

γραμμή, ἡ : *no*, line.

γράφω, γράψω, ἔγρα[ψ/φ]α, γέγραφα, γέγραμμαι, ἐραψάμην : *vb*, draw (a figure).

γωνία, ἡ : *no*, angle.

δεῖ : *vb*, be necessary; δεῖ, it is necessary; ἔδει, it was necassary; δέον, being necessary.

δείκνυμι, δείξω, ἔδειξα, δέδειχα, δέδειγμαι, ἐδείχθην : *vb*, show, demonstrate.

δεικτέον : *ind*, one must show.

δεῖξις -εως, ἡ : *no*, proof.

δείχνῦμι, δείξω, ἔδειξα, δέδειχα, δέδειγμαι, ἐδείχθην : *vb*, show, demonstrate.

δεκαγώνος -ον : *adj*, ten-sided; τὸ δεκαγώνον, *no*, decagon.

δέχομαι, δέξομαι, ἐδεξάμην, —, δέδεγμαι, ἐδέχθην : *vb*, receive, accept.

δή : *conj*, so (explanatory).

δηλαδή : *ind*, quite clear, manifest.

δῆλος -η -ον : *adj*, clear.

δηλονότι : *adv*, manifestly.

διάγω : *vb*, carry over, draw through, draw across; see ἄγω.

διαγώνιος -ον : *adj*, diagonal.

διαλείπω : *vb*, leave an interval between.

διάμετρος -ον : *adj*, diametrical; ἡ διάμετρος, *no*, diameter, diagonal.

διαίρεσις -εως, ἡ : *no*, division, separation.

διαιρέω : *vb*, divide (in two); διαρεθέντος -η -ον, *adj*, separated (ratio); see αἱρέω.

διάστημα -ατος, τό : *no*, radius.

διαφέρω : *vb*, differ; see φέρω.

δίδωμι, δώσω, ἔδωκα, δέδωκα, δέδομαι, ἐδόθην : *vb*, give.

διμοίρος -ον : *adj*, two-thirds.

διπλασιάζω : *vb*, double.

διπλάσιος -α -ον : *adj*, double, twofold.

διπλασίων -ον : *adj*, double, twofold.

διπλοῦς -ῆ -οῦν : *adj*, double.

δίς : *adv*, twice.

δίχα : *adv*, in two, in half.

διχορομία, ἡ : *no*, point of bisection.

δυάς -άδος, ἡ : *no*, the number two, dyad.

δύναμαι : *vb*, be able, be capable, generate, square, be when squared; δυναμένη, ἡ, *no*, square-root (of area)—*i.e.*, straight-line whose square is equal to a given area.

δύναμις -εως, ἡ : *no*, power (usually 2nd power when used in mathematical sence, hence), square.

δυνατός -ή -όν : *adj*, possible.

δωδεκάεδρος -ον : *adj*, twelve-sided.

ἑαυτοῦ -ῆς -οῦ : *adj*, of him/her/it/self, his/her/its/own.

ἐγγίων -ον : *adj*, nearer, nearest.

ἐγγράφω : *vb*, inscribe; see γράφω.

εἶδος -εος, τό : *no*, figure, form, shape.

εἰκοσάεδρος -ον : *adj*, twenty-sided.

εἴρω/λέγω, ἐρῶ/ερέω, εἶπον, εἴρηκα, εἴρημαι, ἐρρήθην : *vb*, say, speak; *per pass part*, ειρημένος -η -ον, *adj*, said, aforementioned.

εἴτε ... εἴτε : *ind*, either ... or.

ἕκαστος -η -ον : *pro*, each, every one.

ἑκατέρος -α -ον : *pro*, each (of two).

ἐκβάλλω, ἐκβαλῶ, ἐκέβαλον, ἐκβεβίωκα, ἐκβέβλημαι, ἐκβληθήν : *vb*, produce (a line).

ἐκθέω : *vb*, set out.

ἔκκειμαι : *vb*, be set out, be taken; see κεῖμαι.

ἐκτίθημι : *vb*, set out; see τίθημι.

ἐκτός : *pre* + *gen*, outside, external.

ἐλά[σσ/ττ]ων -ον : *adj*, less, lesser.

ἐλλείπω : *vb*, be less than, fall short of.

ἐμπίπτω : *vb*, meet (of lines), fall on; see πίπτω.

ἔμπροσθεν : *adv*, in front.

ἐναλλάξ : *adv*, alternate(ly).

ἐναρμόζω : *vb*, insert; *perf indic pass 3rd sg*, ἐνήρμοσται.

ἐνδέχομαι : *vb*, admit, allow.

ἕνεκεν : *ind*, on account of, for the sake of.

ἐνναπλάσιος -α -ον : *adj*, nine-fold, nine-times.

ἔννοια, ἡ : *no*, notion.

ενπεριέχω : *vb*, encompass.

ἐνπίπτω : see ἐμπίπτω.

ἐντός : *pre* + *gen*, inside, interior, within, internal.

ἑξάγωνος -ον : *adj*, hexagonal; τὸ ἑξάγωνον, *no*, hexagon.

ἑξαπλάσιος -α -ον : *adj*, sixfold.

ἑξῆς : *adv*, in order, successively, consecutively.

ἔξωθεν : *adv*, outside, extrinsic.

ἐπάνω : *adv*, above.

ἐπαφή, ἡ : *no*, point of contact.

ἐπεί : *conj*, since (causal).

ἐπειδήπερ : *ind*, inasmuch as, seeing that.

ἐπιζεύγνῡμι, ἐπιζεύξω, ἐπέζευξα, —, ἐπέζευγμαι, ἐπέζεύχθην : *vb*, join (by a line).

ἐπιλογίζομαι : *vb*, conclude.

ἐπινοέω : *vb*, think of, contrive.

ἐπιπέδος -ον : *adj*, level, flat, plane; τὸ ἐπιπέδον, *no*, plane.

ἐπισκέπτομαι : *vb*, investigate.

ἐπίσκεψις -εως, ἡ : *no*, inspection, investigation.

ἐπιτάσσω : *vb*, put upon, enjoin; τὸ ἐπιταχθέν, *no*, the (thing) prescribed; see τάσσω.

ἐπίτριτος -ον : *adj*, one and a third times.

ἐπιφάνεια, ἡ : *no*, surface.

ἕπομαι : *vb*, follow.

ἔρχομαι, ἐλεύσομαι, ἦλθον, ἐλήλυθα, —, — : *vb*, come, go.

ἔσχατος -η -ον : *adj*, outermost, uttermost, last.

ἑτερόμηκης -ες : *adj*, oblong; τὸ ἑτερόμηκες, *no*, rectangle.

ἕτερος -α -ον : *adj*, other (of two).

ἔτι : *par*, yet, still, besides.

εὐθύγραμμος -ον : *adj*, rectilinear; τὸ εὐθύγραμμον, *no*, rectilinear figure.

εὐθύς -εῖα -ύ : *adj*, straight; ἡ εὐθεῖα, *no*, straight-line; ἐπ᾽ εὐθεῖας, in a straight-line, straight-on.

εὑρίσκω, εὑρήσκω, ηὗρον, εὕρεκα, εὕρημαι, εὑρέθην : *vb*, find.

ἐφάπτω : *vb*, bind to; *mid*, touch; ἡ ἐφαπτομένη, *no*, tangent; see ἅπτω.

ἐφαρμόζω, ἐφαρμόσω, ἐφήρμοσα, ἐφήμοκα, ἐφήμοσμαι, ἐφήμόσθην : *vb*, coincide; *pass*, be applied.

ἐφεξῆς : *adv*, in order, adjacent.

ἐφίστημι : *vb*, set, stand, place upon; see ἵστημι.

ἔχω, ἕξω, ἔσχον, ἔσχηκα, -έσχημαι, — : *vb*, have.

ἡγέομαι, ἡγήσομαι, ἡγησάμην, ἥγημαι, —, ἡγήθην : *vb*, lead.

ἤδη : *ind*, already, now.

ἥκω, ἥξω, —, —, —, — : *vb*, have come, be present.

ἡμικύκλιον, τό : *no*, semi-circle.

ἡμιόλιος -α -ον : *adj*, containing one and a half, one and a half times.

ἥμισυς -εια -υ : *adj*, half.

ἤπερ = ἤ + περ : *conj*, than, than indeed.

ἤτοι ... ἤ : *par*, surely, either ... or; in fact, either ... or.

θέσις -εως, ἡ : *no*, placing, setting, position.

θεωρημα -ατος, τό : *no*, theorem.

ἴδιος -α -ον : *adj*, one's own.

ἰσάκις : *adv*, the same number of times; ἰσάκις πολλαπλάσια, the same multiples, equal multiples.

ἰσογώνιος -ον : *adj*, equiangular.

ἰσόπλευρος -ον : *adj*, equilateral.

ἰσοπληθής -ές : *adj*, equal in number.

ἴσος -η -ον : *adj*, equal; ἐξ ἴσου, equally, evenly.

ἰσοσκελής -ές : *adj*, isosceles.

ἵστημι, στήσω, ἔστησα, —, —, ἐσταθην : *vb tr*, stand (something).

ἵστημι, στήσω, ἔστην, ἕστηκα, ἕσταμαι, ἐσταθην : *vb intr*, stand up (oneself); Note: perfect *I have stood up* can be taken to mean present *I am standing*.

ἰσοϋψής -ές : *adj*, of equal height.

καθάπερ : *ind*, according as, just as.

κάθετος -ον : *adj*, perpendicular.

καθόλου : *adv*, on the whole, in general.

καλέω : *vb*, call.

κἀκεινος = καὶ ἐκεῖνος .

κἄν = καὶ ἄν : *ind*, even if, and if.

καταγραφή, ἡ : *no*, diagram, figure.

καταγράφω : *vb*, describe/draw, inscribe (a figure); see γράφω.

κατακολουθέω : *vb*, follow after.

καταλείπω : *vb*, leave behind; see λείπω; τὰ καταλειπόμενα, *no*, remainder.

κατάλληλος -ον : *adj*, in succession, in corresponding order.

καταμετρέω : *vb*, measure (exactly).

καταντάω : *vb*, come to, arrive at.

κατασκευάζω : *vb*, furnish, construct.

κεῖμαι, κεῖσομαι, —, —, —, — : *vb*, have been placed, lie, be made; see τίθημι.

κέντρον, τό : *no*, center.

κλάω : *vb*, break off, inflect.

κλίνω, κλίνω, ἔκλινα, κέκλικα, κέκλιμαι, ἐκλίθην : *vb*, lean, incline.

κλίσις -εως, ἡ : *no*, inclination, bending.

κοῖλος -η -ον : *adj*, hollow, concave.

κορυφή, ἡ : *no*, top, summit, apex; κατὰ κορυφήν, vertically opposite (of angles).

κρίνω, κρινῶ, ἔκρῖνα, κέκρικα, κέκριμαι, ἐκρίθην : *vb*, judge.

κύβος, ὁ : *no*, cube.

κύκλος, ὁ : *no*, circle.

κύλινδρος, ὁ : *no*, cylinder.

κυρτός -ή -όν : *adj*, convex.

κῶνος, ὁ : *no*, cone.

λαμβάνω, λήψομαι, ἔλαβον, εἴληφα εἴλημμαι, ἐλήφθην : *vb*, take.

λέγω : *vb*, say; *pres pass part*, λεγόμενος -η -ον, *no*, so-called; see ἔιρω.

λείπω, λείψω, ἔλιπον, λέλοιπα, λέλειμμαι, ἐλείφθην : *vb*, leave, leave behind.

λημμάτιον, τό : *no*, diminutive of λῆμμα.

λῆμμα -ατος, τό : *no*, lemma.

λῆψις -εως, ἡ : *no*, taking, catching.

λόγος, ὁ : *no*, ratio, proportion, argument.

λοιπός -ή -όν : *adj*, remaining.

μανθάνω, μαθήσομαι, ἔμαθον, μεμάθηκα, —, — : *vb*, learn.

μέγεθος -εος, τό : *no*, magnitude, size.

μείζων -ον : *adj*, greater.

μένω, μενῶ, ἔμεινα, μεμένηκα, —, — : *vb*, stay, remain.

μέρος -ους, τό : *no*, part, direction, side.

μέσος -η -ον : *adj*, middle, mean, medial; ἐκ δύο μέσων, bimedial.

μεταλαμβάνω : *vb*, take up.

μεταξύ : *adv*, between.

μετέωρος -ον : *adj*, raised off the ground.

μετρέω : *vb*, measure.

μέτρον, τό : *no*, measure.

μηδείς, μηδεμία, μηδέν : *adj*, not even one, (neut.) nothing.

μηδέποτε : *adv*, never.

μηδέτερος -α -ον : *pro*, neither (of two).

μῆκος -εος, τό : *no*, length.

μήν : *par*, truely, indeed.

μονάς -άδος, ἡ : *no*, unit, unity.

μοναχός -ή -όν : *adj*, unique.

μοναχῶς : *adv*, uniquely.

μόνος -η -ον : *adj*, alone.

νοέω, —, νόησα, νενόηκα, νενόημαι, ἐνοήθην : *vb*, apprehend, conceive.

οἷος -α -ον : *pre*, such as, of what sort.

ὀκτάεδρος -ον : *adj*, eight-sided.

ὅλος -η -ον : *adj*, whole.

ὁμογενής -ές : *adj*, of the same kind.

ὅμοιος -α -ον : *adj*, similar.

ὁμοιοπληθής -ές : *adj*, similar in number.

ὁμοιοταγής -ές : *adj*, similarly arranged.

ὁμοιότης -ητος, ἡ : *no* similarity.

ὁμοίως : *adv*, similarly.

ὁμόλογος -ον : *adj*, corresponding, homologous.

ὁμοταγής -ές : *adj*, ranged in the same row or line.

ὁμώνυμος -ον : *adj*, having the same name.

ὄνομα -ατος, τό : *no*, name; ἐκ δύο ὀνομάτων, binomial.

ὀξυγώνιος -ον : *adj*, acute-angled; τὸ ὀξυγώνιον, *no*, acute angle.

ὀξύς -εῖα -ύ : *adj*, acute.

ὁποιοσοῦν = ὁποῖος -α -ον + οὖν : *adj*, of whatever kind, any kind whatsoever.

ὁπόσος -η -ον : *pro*, as many, as many as.

ὁποσοσδηποτοῦν = ὁπόσος -η -ον + δή + ποτέ + οὖν : *adj*, of whatever number, any number whatsoever.

ὁποσοσοῦν = ὁπόσος -η -ον + οὖν : *adj*, of whatever number, any number whatsoever.

ὁπότερος -α -ον : *pro*, either (of two), which (of two).

ὀρθογώνιον, τό : *no*, rectangle, right-angle.

ὀρθός -ή -όν : *adj*, straight, right-angled, perpendicular; πρὸς ὀρθὰς γωνίας, at right-angles.

ὅρος, ὁ : *no*, boundary, definition, term (of a ratio).

ὁσαδηποτοῦν = ὅσα + δή + ποτέ + οὖν : *ind*, any number whatsoever.

ὁσάκις : *ind*, as many times as, as often as.

ὁσαπλάσιος -ον : *pro*, as many times as.

ὅσος -η -ον : *pro*, as many as.

ὅσπερ, ἥπερ, ὅπερ : *pro*, the very man who, the very thing which.

ὅστις, ἥτις, ὅ τι : *pro*, anyone who, anything which.

ὅταν : *adv*, when, whenever.

ὁτιοῦν : *ind*, whatsoever.

οὐδείς, οὐδεμία, οὐδέν : *pro*, not one, nothing.

οὐδέτερος -α -ον : *pro*, not either.

οὐθέτερος : see οὐδέτερος.

οὐθέν : *ind*, nothing.

οὖν : *adv*, therefore, in fact.

οὕτως : *adv*, thusly, in this case.

πάντως : *adv*, in all ways.

παρὰ : *prep* + *acc*, parallel to.

παραβάλλω : *vb*, apply (a figure); see βάλλω.

παραβολή, ἡ : *no*, application.

παράκειμαι : *vb*, lie beside, apply (a figure); see κεῖμαι.

παραλλάσσω, παραλλάξω, —, παρήλλαχα, —, — : *vb*, miss, fall awry.

παραλληλεπίπεδος, -ον : *adj*, with parallel surfaces; τὸ παραλληλεπίπεδον, *no*, parallelepiped.

παραλληλόγραμμος -ον : *adj*, bounded by parallel lines; τὸ παραλληλόγραμμον, *no*, parallelogram.

παράλληλος -ον : *adj*, parallel; τὸ παράλληλον, *no*, parallel, parallel-line.

παραπλήρωμα -ατος, τό : *no*, complement (of a parallelogram).

παρατέλυετος -ον : *adj*, penultimate.

παρέκ : *prep* + *gen*, except.

παρεμπίπτω : *vb*, insert; see πίπτω.

πάσχω, πείσομαι, ἔπαθον, πέπονθα, —, — : *vb*, suffer.

πεντάγωνος -ον : *adj*, pentagonal; τὸ πεντάγωνον, *no*, pentagon.

πενταπλάσιος -α -ον : *adj*, five-fold, five-times.

πεντεκαιδεκάγωνον, τό : *no*, fifteen-sided figure.

πεπερασμένος -η -ον : *adj*, finite, limited; see περαίνω.

περαίνω, περανῶ, ἐπέρανα, —, πεπέρανμαι, ἐπερανάνθην : *vb*, bring to end, finish, complete; *pass*, be finite.

πέρας -ατος, τό : *no*, end, extremity.

περατόω, —, —, —, —, — : *vb*, bring to an end.

περιγράφω : *vb*, circumscribe; see γράφω.

περιέχω : *vb*, encompass, surround, contain, comprise; see ἔχω.

περιλαμβάνω : *vb*, enclose; see λαμβάνω.

περιλείπομαι : *vb*, remain over, be left over.

περισσάκις : *adv*, an odd number of times.

περισσός -ή -όν : *adj*, odd.

περιφέρεια, ἡ : *no*, circumference.

περιφέρω : *vb*, carry round; see φέρω.

πηλικότης -ητος, ἡ : *no*, magnitude, size.

πίπτω, πεσοῦμαι, ἔπεσον, πέπτωκα, —, — : *vb*, fall.

πλάτος -εος, τό : *no*, breadth, width.

πλείων -ον : *adj*, more, several.

πλευρά, ἡ : *no*, side.

πλῆθος -εος, τὸ : *no*, great number, multitude, number.

πλήν : *adv* & *prep* + *gen*, more than.

ποιός -ά -όν : *adj*, of a certain nature, kind, quality, type.

πολλαπλασιάζω : *vb*, multiply.

πολλαπλασιασμός, ὁ : *no*, multiplication.

πολλαπλάσιον, τό : *no*, multiple.

πολύεδρος -ον : *adj*, polyhedral; τό πολύεδρον, *no*, polyhedron.

πολύγωνος -ον : *adj*, polygonal; τό πολύγωνον, *no*, polygon.

πολύπλευρος -ον : *adj*, multilateral.

πόρισμα -ατος, τό : *no*, corollary.

ποτέ : *ind*, at some time.

πρῖσμα -ατος, τὸ : *no*, prism.

προβαίνω : *vb*, step forward, advance.

προδείκνυμι : *vb*, show previously; see δείκνυμι.

προεκτίθημι : *vb*, set forth beforehand; see τίθημι.

προερέω : *vb*, say beforehand; *perf pass part*, προειρημένος -η -ον, *adj*, aforementioned; see εἴρω.

προσαναπληρόω : *vb*, fill up, complete.

προσαναγράφω : *vb*, complete (tracing of); see γράφω.

προσαρμόζω : *vb*, fit to, attach to.

προσεκβάλλω : *vb*, produce (a line); see ἐκβάλλω.

προσευρίσκω : *vb*, find besides, find; see εὑρίσκω.

προσλαμβάμω : *vb*, add.

προκειμαι : *vb*, set before, prescribe.

πρόσκειμαι : *vb*, be laid on, have been added to; see κεῖμαι.

προσπίπτω : *vb*, fall on, fall toward, meet; see πίπτω.

προτασις -εως, ἡ : *no*, proposition.

προστάσσω : *vb*, prescribe, enjoin; τὸ τροσταχθέν, *no*, the thing prescribed; see τάσσω.

προστίθημι : *vb*, add; see τίθημι.

πρότερος -α -ον : *adj*, first (comparative), before, former.

προτίθημι : *vb*, assign; see τίθημι.

προχωρέω : *vb*, go/come forward, advance.

πρῶτος -α -ον : *adj*, first, prime.

πυραμίς -ίδος, ἡ : *no*, pyramid.

ῥητός -ή -όν : *adj*, expressible, rational.

ῥομβοειδής -ές : *adj*, rhomboidal; τὸ ῥομβοειδές, *no*, romboid.

ῥόμβος, ὁ *no*, rhombus.

σημεῖον, τό : *no*, point.

σκαληνός -ή -όν : *adj*, scalene.

στερεός -ά -όν : *adj*, solid; τὸ στερεόν, *no*, solid, solid body.

στοιχεῖον, τό : *no*, element.

στρέφω, -στρέψω, ἔστρεψα, **—**, ἐσταμμαι, ἐστάφην : *vb*, turn.

σύγκειμαι : *vb*, lie together, be the sum of, be composed; συγκείμενος -η -ον, *adj*, composed (ratio), compounded; see κεῖμαι.

σύγκρίνω : *vb*, compare; see κρίνω.

συμβαίνω : *vb*, come to pass, happen, follow; see βαίνω.

συμβάλλω : *vb*, throw together, meet; see βάλλω.

σύμμετρος -ον : *adj*, commensurable.

σύμπας -αντος, ὁ : *no*, sum, whole.

συμπίπτω : *vb*, meet together (of lines); see πίπτω.

συμπληρόω : *vb*, complete (a figure), fill in.

συνάγω : *vb*, conclude, infer; see ἄγω.

συναμφότεροι -αι -α : *adj*, both together; ὁ συναμφότερος, *no*, sum (of two things).

συναποδείκνυμι : *no*, demonstrate together; see δείκνυμι.

συναφή, ἡ : *no*, point of junction.

σύνδυο, οἱ, αἱ, τά : *no*, two together, in pairs.

συνεχής -ές : *adj*, continuous; κατὰ τὸ συνεχές, continuously.

σύνθεσις -εως, ἡ : *no*, putting together, composition.

σύνθετος -ον : *adj*, composite.

συ[ν]ίστημι : *vb*, construct (a figure), set up together; *perf imperat pass 3rd sg*, συνεστάτω; see ἵστημι.

συντίθημι : *vb*, put together, add together, compound (ratio); see τίθημι.

σχέσις -εως, ἡ : *no*, state, condition.

σχῆμα -ατος, τό : *no*, figure.

σφαῖρα -ας, ἡ : *no*, sphere.

τάξις -εως, ἡ : *no*, arrangement, order.

ταράσσω, ταράξω, **—**, **—**, τετάραγμαι, ἐταράχθην : *vb*, stir, trouble, disturbe; τεταραγμένος -η -ον, *adj*, disturbed, perturbed.

τάσσω, τάξω, ἔταξα, τέταχα, τέταγμαι, ἐτάχθην : *vb*, arrange, draw up.

τέλειος -α -ον : *adj*, perfect.

τέμνω, τεμνῶ, ἔτεμον, -τέτμηκα, τέτμημαι, ἐτμήθην : *vb*, cut; *pres/fut indic act 3rd sg*, τέμει.

τεταρτημοριον, τὸ : *no*, quadrant.

τετράγωνος -ον : *adj*, square; τὸ τετράγωνον, *no*, square.

τετράκις : *adv*, four times.

τετραπλάσιος -α -ον : *adj*, quadruple.

τετράπλευρος -ον : *adj*, quadrilateral.

τετραπλόος -η -ον : *adj*, fourfold.

τίθημι, θήσω, ἔθηκα, τέθηκα, κεῖμαι, ἐτέθην : *vb*, place, put.

τμῆμα -ατος, τό : *no*, part cut off, piece, segment.

τοίνυν : *par*, accordingly.

τοιοῦτος -αύτη -οῦτο : *pro*, such as this.

τομεύς -έως, ὁ : *no*, sector (of circle).

τομή, ἡ : *no*, cutting, stump, piece.

τόπος, ὁ : *no*, place, space.

τοσαυτάκις : *adv*, so many times.

τοσαυταπλάσιος -α -ον : *pro*, so many times.

τοσοῦτος -αύτη -οῦτο : *pro*, so many.

τουτέστι = τοῦτ᾽ ἔστι : *par*, that is to say.

τραπέζιον, τό : *no*, trapezium.

τρίγωνος -ον : *adj*, triangular; τὸ τρίγωνον, *no*, triangle.

τριπλάσιος -α -ον : *adj*, triple, threefold.

τρίπλευρος -ον : *adj*, trilateral.

τριπλ-όος -η -ον : *adj*, triple.

τρόπος, ὁ : *no*, way.

τυγχάνω, τεύξομαι, ἔτυχον, τετύχηκα, τέτευγμαι, ἐτεύχθην : *vb*, hit, happen to be at (a place).

ὑπάρχω : *vb*, begin, be, exist; see ἄρχω.

ὑπεξαίρεσις -εως, ἡ : *no*, removal.

ὑπερβάλλω : *vb*, overshoot, exceed; see βάλλω.

ὑπεροχή, ἡ : *no*, excess, difference.

ὑπερέχω : *vb*, exceed; see ἔχω.

ὑπόθεσις -εως, ἡ : *no*, hypothesis.

ὑπόκειμαι : *vb*, underlie, be assumed (as hypothesis); see κεῖμαι.

ὑπολείπω : *vb*, leave remaining.

ὑποτείνω, ὑποτενῶ, ὑπέτεινα, ὑποτέτακα, ὑποτέταμαι, ὑπετάθην : *vb*, subtend.

ὕψος -εος, τό : *no*, height.

φανερός -ά -όν : *adj*, visible, manifest.

φημὶ, φήσω, ἔφην, —, —, — : *vb*, say; ἔφαμεν, we said.

φέρω, οἴσω, ἤνεγκον, ἐνήνοχα, ἐνήνεγμαι, ἠνέχθην : *vb*, carry.

χώριον, τό : *no*, place, spot, area, figure.

χωρίς : *pre + gen*, apart from.

ψαύω : *vb*, touch.

ὡς : *par*, as, like, for instance.

ὡς ἔτυχεν : *par*, at random.

ὡσαύτως : *adv*, in the same manner, just so.

ὥστε : *conj*, so that (causal), hence.