A PRIMARY ASTRONOMY,

FOR

SCHOOLS AND FAMILIES:

ADAPTED TO THE CAPACITY OF YOUTH, AND ILLUSTRATED BY NEARLY

TWO HUNDRED ENGRAVINGS.

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ETC. ETC.

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SUGGESTIONS TO TEACHERS AND STUDENTS.

1. The *coarse print* should generally be committed to memory, as an answer to the questions.

2. The *fine print* and the *cuts* should be carefully *studied;* and the student should be prepared, if called upon, to make drawings upon the blackboard similar to those found in the lessons.

3. In studying the illustrations, the pupil should generally imagine himself to be looking *South*—the top of the book, held up before him, being *North;* the bottom *South;* the left hand *East;* and the right hand *West.*

4. The teacher should call upon the several members of the class, in succession, to sketch the diagrams as they occur in the lesson, and to show how they illustrate the point under consideration—this explanation being in all cases extemporaneous.

5. The *Pronunciation*, *Definition*, and *Derivation* of terms should receive special attention; and to facilitate such inquiries, important words are not only pronounced and defined, but are traced to their original source.

6. Finally, whenever practicable, let the objects or phenomena described in the lessons be looked up and observed as they really appear in nature. This will invest the subject with new interest, and will excite in the mind of the student a desire to know more of this most wonderful and most sublime of all human studies.

New York, January, 1851.

PRIMARY ASTRONOMY.

PART I.

PRELIMINARY OBSERVATIONS AND DEFINITIONS.

LESSON I.

HISTORY OF ASTRONOMY.

1. QUESTION.—*What is* ASTRONOMY?

ANSWER.—It is the science of the Heavenly Bodies—the Sun, Moon, Planets, Comets, and Stars.

2. *What does it teach respecting these bodies?*

Their names, distances, magnitudes, and motions, and the causes of Day and Night, the Seasons, Eclipses, Tides, and various other phenomena.*

3. *Was Astronomy known to the ancients?*

It was; and was taught in Egypt, Chaldea, India, China, and Greece long before the birth of Christ.

4. *What was the occupation of the first Astronomers?*

They were shepherds and herdsmen.

5. *By what were they led to this study?*

By observing the movements of the sun, moon, and stars, while watching their flocks from year to year in the open fields.†

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* PHE-NOM′-E-NA, appearances; things presented to the eye, or events seen to take place. The singular of this term is *Phe-nom-e-non.*

† Norton's Elementary Treatise, page 2.

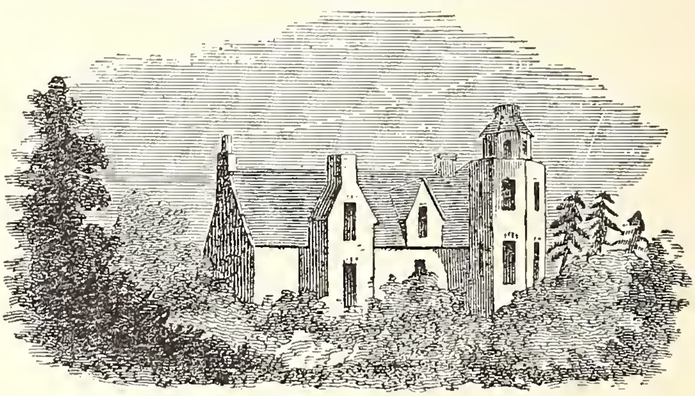
ANCIENT ASTRONOMERS OBSERVING THE HEAVENS.

6. *Where do modern Astronomers make their observations?*

In what are called *Observatories.*

[An observatory is a place erected for the purpose of observing the heavens. The most celebrated in this country is the one erected by Professor Mitchel on Mount Adams, Cincinnati. Besides this, there is one at Washington, one at Philadelphia, one at Cambridge, Mass., &c. An effort is now being made (1850) to erect one on Brooklyn Hights, Long Island. A good private observatory, owned by Lewis M. Rutherford, Esq., may be seen in the rear of his residence, corner of Second Avenue and Eleventh street, New York City.]

DR. DICK'S OBSERVATORY, NEAR DUNDEE, SCOTLAND.

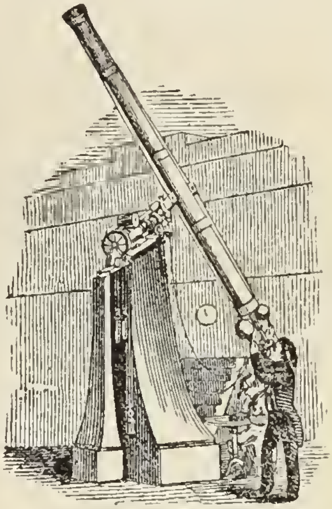


7. *What other advantage have modern Astronomers?*

They are assisted by many useful *instruments*, the most important of which is the *Telescope.**

* From the Greek *tele*, at a distance, and *skopeo*, to see.

MODERN ASTRONOMERS USING A TELESCOPE.



[This is a picture of the *Great Refracting Telescope* of the Cincinnati Observatory. It is reduced and copied from a cut in the first number of the *Sidereal Messenger*, July, 1846. The original (which is an enlargement of a daguerreotype) is exceedingly accurate and beautiful, and our artist has given us an exact miniature of it in the page before you.

This Telescope has an object-glass (placed in the top of the tube toward the *objects* to be seen) which is twelve inches in diameter. The tube, which is seventeen feet long, and the Telescope, alone cost $9,437. It was made at Munich, in Germany.]

8. *What did the ancients think of the form of the earth?*

Instead of a globe inhabited on all sides, they believed it to be a plane, inhabited on one side only.

9. *What did they think of her motions, and those of the heavenly bodies?*

They believed the earth to be at rest in the center of the universe, and that the sun, moon, and stars actually revolved around her, from east to west, as they appear to do, every twenty-four hours.

[It is by no means strange that the ancients were thus deceived by appearances. Seeing but a small portion of the earth at any one time, they were easily misled in regard to its form; and having no idea of its revolution, it was natural to suppose that the apparent daily revolution of the heavenly bodies westward was real. In the same manner persons often attribute their own motions to bodies that are at rest, especially when carried swiftly forward without any apparent cause (as when one travels in a steamboat or railway car), and when for a time they forget their own motions.]

10. *What other notions had the ancients in respect to the figure of the earth?*

That it was longest from east to west.

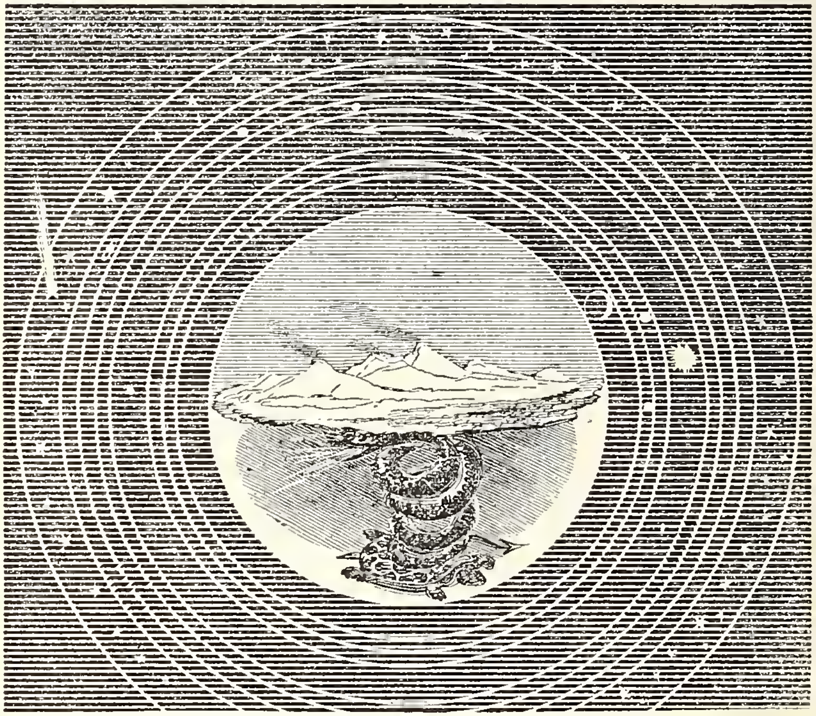
[They observed that traveling east or west had no effect upon the apparent position of the stars, while going north and south did. Hence the conclusion that the earth was narrowest north and south. This erroneous idea was the origin of our modern terms, *latitude* and *longitude*, the last of which means *length*, and the former *breadth*.]

11. *What was the ancient system of Astronomy called, and why?*

The *Ptolemaic** *Theory*, from Ptolemy,† an Egyptian philosopher, who flourished in the second century of the Christian era.

[1. The word *Ptolemy* was a common name for the successive Egyptian princes, as Pharaoh‡ was for the kings of Egypt in the days of Moses.

PTOLEMAIC THEORY OF THE STRUCTURE OF THE UNIVERSE.



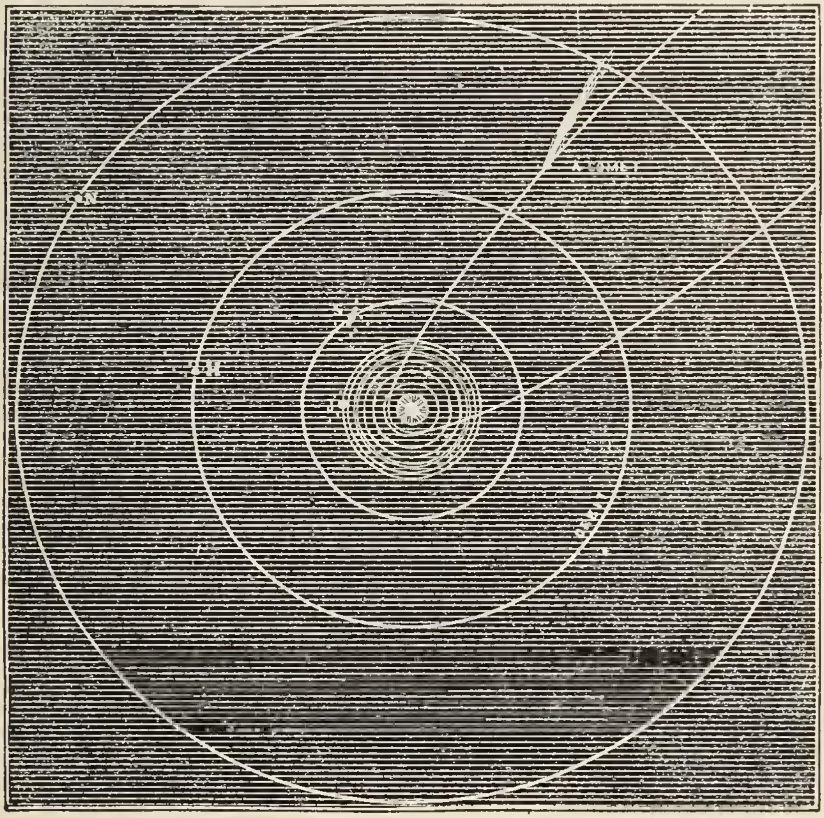
2. The ancients supposed the earth to be surrounded by eight crystalline arches or spheres, one within the other, in which the sun, moon, and stars were set. In this way they accounted for their not falling down upon the earth, while the light of the most distant of the stars could pass through the transparent crystal till it reached the earth. The moon was supposed to be in the first sphere, the sun in the fourth, and the fixed stars in the eighth or highest sphere. The cut is intended to illustrate all these particulars.

3. This erroneous theory was embarrassed by numerous and pressing difficulties, one of which was to ascertain what upheld the earth. In the effort to explain this mystery several remarkable notions were adopted, one of which is represented in the cut. The earth is seen as a plane, resting upon the head of a huge serpent, which, in turn, is upheld by a tortoise. The sun, moon, and stars are shown revolving around the earth. This absurd theory was generally believed to be correct till about the middle of the sixteenth century, or 300 years ago.]

* Pronounced TOL-E-MA′-IC. † TOL′-E-MY. ‡ FA′-RO.

LESSON II.

THE MODERN, OR COPERNICAN SYSTEM.



12. *Describe the modern or true theory.*

It represents the sun as the fixed center, around which the earth and other planets revolve.

13. *What does it teach respecting the form of the earth?*

That it is a *Sphere* or *Globe.*

14. *To what does it attribute the apparent westward revolution of the sun, moon, and stars?*

To the actual revolution of the earth eastward upon its axis every twenty-four hours.

[If a *fly* were placed upon an artificial globe in a room where several lamps were suspended, and the globe were made to revolve, he would be likely to conclude, if he could reason, that tne *lamps* revolved around him, especially if he was firmly fixed upon the globe, and had no suspicion of his own motion. In the same manner the ancients concluded the heavens revolved instead of themselves.]

15. *What is the modern system of Astronomy called, and why?*

The COPERNICAN THEORY, after *Copernicus*, a Prussian* astronomer, who taught it.

16. *When and where was Copernicus born?*

In Thorn, in Prussia, in 1473.

17. *When did he begin to propagate his theory?*

About the year 1510.

[This was about 18 years after the discovery of America by Columbus, or 340 years ago.]

18. *Was this theory entirely unknown before?*

It is supposed to have been taught by *Pythagoras*,† a Greek philosopher, about 500 years before Christ.

19. *Who next taught it after Copernicus?*

Galileo, the inventor of the Telescope.

20. *How were his doctrines received?*

They were pronounced erroneous, and he was obliged to renounce them.

[The world has always been slow to receive new discoveries and improvements. The discovery of the circulation of the blood, by Harvey, met with the most decided opposition, and the first steamboat ever constructed was called "Fulton's folly," in ridicule of Robert Fulton, its distinguished inventor. It is not strange, therefore, that a theory so much at variance with the *apparent* phenomena of the heavens as was that of Copernicus, should be considered erroneous, and be violently opposed.]

21. *What proof have we that the earth is round, from the appearance of the heavenly bodies?*

The obvious figure of the sun, moon, and stars seems to indicate that all worlds are spherical, and consequently that the earth is a globe.

[This reason for believing the earth to be a sphere would have little weight where the true system of Astronomy was not first understood; for it assumes that the sun,

* PRU'-SHAN. † PY-THAG'-O-RAS.

moon, and stars, which are seen to be round, are *worlds;* and as all worlds of which we can see the shape are round, the inference is that the earth also is round.]

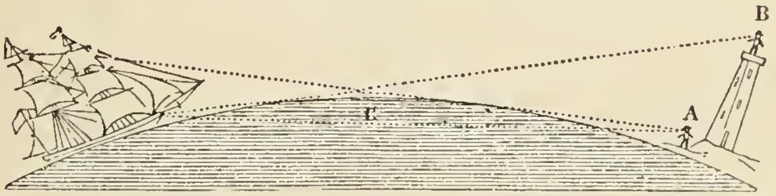
22. *What proof from the appearance of the earth's surface?*

The convexity* of the earth's surface shows it to be a globe or ball.

23. *How do we know that the earth's surface is convex?*

It is evident from the fact that the masts of a ship, approaching us from sea, are always seen before the hull; and the higher the observer is on the shore, the more of the ship will he see.†

CONVEXITY OF THE EARTH'S SURFACE.



[Here the observer upon the shore at A sees only the top-masts of the ship, while the man standing upon the pillar at B sees the masts and sails, and part of the hull. Now if the water between A and the ship were exactly flat instead of convex, the vision of A would extend along the line C, and he could see the whole ship as well as B. The advantage of B over A, in consequence of his elevation, shows that the surface of the waters is convex between A and the ship.]

24. *What additional proof have we that the earth's surface is convex?*

In constructing aqueducts‡ it is found necessary to have the middle elevated a little above the plane of the ends, otherwise the water will run over in the middle before the ends are full.

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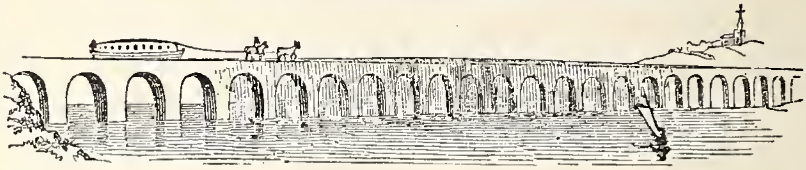
* Con-vex'-i-ty, swelling toward a globular form; roundness.

† It would be well, where there is time, during recitation, for some member of the Class to draw this and similar figures used for illustration upon the Blackboard, and explain the same in the hearing of the Teacher.

‡ Ak'-we-duct, a structure for conveying water from one place to another, as across rivers, &c.

CONVEXITY DISCOVERED IN THE BUILDING OF AQUEDUCTS.

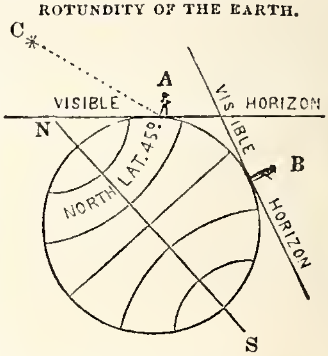


[In the cut, the top of the aqueduct is perfectly flat; but the water, on being let in, conforms to the general figure of the globe, swells upward in the middle, and runs over. This proves the surface of the water to be convex. The amount of this convexity is found to be about eight inches to a mile.]

25. *What fourth proof can you offer that the earth is a globe or ball?*

As we go north upon its surface the stars in the south seem to go down, till they sink below the horizon.*

ROTUNDITY OF THE EARTH.



[The same is true of the northern stars when we go south, and this is precisely what would occur if the earth were a globe. In the figure, the observer at A sees the star C elevated about 40 degrees above his horizon. As he recedes toward his position at B, the star seems to sink toward the earth, till at length it goes down or out of sight. The convex surface of the earth is now between the star and the observer. This elevation and depression of the North Star, caused by the observer's change of position, enables the mariner to determine his latitude upon the trackless deep; for as every degree he sails northward causes the Pole Star to rise one degree, it follows that the apparent *altitude* of the star and the *latitude* of the observer are the same; the former being ascertained, the latter is at once known.]

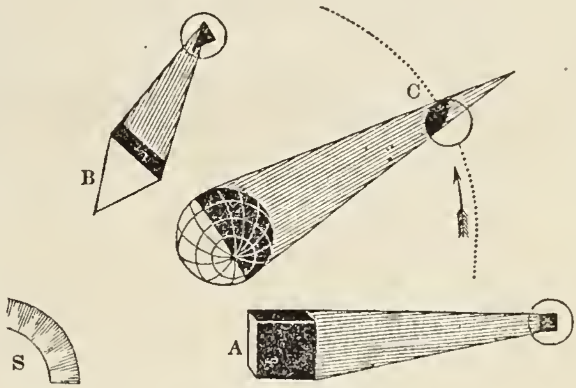
26. *What is the fifth proof that the earth is a globe?*

The shadow of the earth, when seen upon the surface of the moon, in an eclipse, is convex; which shows the earth, from which the shadow is projected, to be convex also.

[1. It is not pretended that this reasoning is altogether logical and conclusive, for any circular object, like a common plate, will cast a convex shadow, if held in a certain position. Still, as the earth revolves, and in all positions casts a convex shadow, it is strong presumptive proof that the earth is a sphere, as no other form would always cast such a shadow under the same circumstances.

* Ho-ri'-zon.

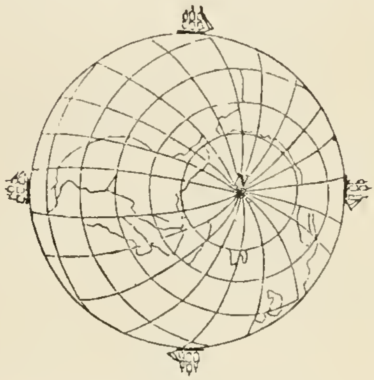
2. In this cut the shadow of different objects is exhibited. At A the object is of a cubical form, and casts a shadow accordingly upon the moon at the right. At B the object is triangular or prismatic, and the shadow is triangular; but the shadow of the earth, as shown at C, is *circular*, indicating the globular form of the earth. An observer may be seen on the upper side of the earth, within the shadow, looking at the eclipse.]



CONVEXITY OF THE EARTH'S SHADOW.

27. *State the last proof that the earth is a globe.*

It is certain from the fact that many ships have sailed quite around it, going westward till they came to the point whence they started.


SHIPS SAILING AROUND THE WORLD.

[*Ferdinand Magellan*, a Portuguese, was the first person who sailed around the world. He sailed from Seville, in Spain, in 1521. It is now quite common for ships to go to China by Cape Horn, and return by the Cape of Good Hope, thus circumnavigating the globe.]

28. *What proof have we that the earth revolves or turns over?*

The apparent revolution of the sun, moon, and stars, from east to west, every twenty-four hours, shows the real revolution of the earth from west to east in the same time.

[1. That the earth revolves upon its axis may be inferred from the fact that a sphere is well adapted to such a revolution, and that it is impossible for man to project a ball through space without having it revolve on its axis at the same time.

2. That the heavenly bodies *appear* to revolve westward, is no proof that they are actually in motion. We often transfer our own motion, in imagination, to bodies that are at rest, as already shown at Question 9. "Copernicus tells us that he was first led to think that the apparent motions of the heavenly bodies, in their diurnal revolution, were owing to the real motion of the earth in the opposite direction, from observing instances of the same kind among terrestrial objects; as when the shore seems to the mariner to recede as he rapidly sails from it; and as trees and other objects seem

to glide by us, when, on riding swiftly past them, we lose the consciousness of our own motion."

3. For the sun and fixed stars to revolve daily around the earth would require an inconceivable velocity. To perform their respective journeys, the sun would have to fly onward at the rate of 25 millions of miles per hour, or 69,440 miles per second; and the nearest fixed stars at the rate of 14,000 millions of miles per second, or 70,000 times as swift as light!

4. The obvious design of the sun is "to rule the day," and give us the agreeable vicissitudes of day and night. Now for the sun to go around the earth, to enlighten and warm its different sides, would be like carrying the fireplace around a person, in order to warm him. It was in view of this absurdity in the Ptolemaic theory that an ancient philosopher said that if he had made the universe, he could have made it better than the gods had made it.

5. The whole Copernican system, of which the revolution of the earth is a leading principle, is demonstrated to be correct by the prediction of Eclipses and Transits, with the greatest possible exactness, and for years before they take place. These calculations are all based upon the truth of the Copernican theory, and if the theory was not correct the predictions would fail; but as they do not, it follows that the theory upon which they are based is correct.]

LESSON III.

GEOMETRICAL DEFINITIONS.*

29. *What is a Solid or Body?*

It is any thing having length, breadth, and thickness.

30. *Describe a surface.*

It is the *outside* or *exterior* of a body, and has length and breadth only.

31. *How are surfaces distinguished?*

Into *Plane*, *Convex*, and *Concave*.

[A surface may also be ***rough*** or ***smooth***, ***hard*** or ***soft***, but the question has reference to the general figure of bodies, and the answer is given accordingly.]

32. *What is a Plane Surface?*

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* As some knowledge of geometrical terms and figures is necessary in the study of Astronomy, two lessons upon the subject are here inserted for the benefit of those students who have not studied Geometry. An introduction to some of its first principles, in this connection, will probably awaken a desire in the minds of such students, to become further acquainted with this beautiful and sublime study.

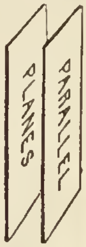
It is a surface that is perfectly flat, like the top of a table or the side of a wall.*

[1. We may imagine what is called a *plane*, to extend off beyond the *plane surface* as far as we please; or, in other words, to be *indefinitely extended.* When a plane or a line is extended in this way, it is said to be *produced.*

2. An imaginary plane may exist where there is no *body* having a plane surface; or between two lines, like the plane of a circle. A sheet of tin, laid across a small wire hoop, would represent the plane of that circle, in whatever position it might be held, whether horizontally, perpendicularly, or otherwise; and the place which the tin would pass through, if extended to the starry heavens, is the plane of that circle.

3. All objects which the tin would touch or *cut*, if extended outward to the heavens, or to infinity, are *in the plane* of the sheet, or the circle upon which it is laid. A point is in a plane produced, when the plane continued or extended would pass through that point.]

33. *When are Planes said to be Parallel?*

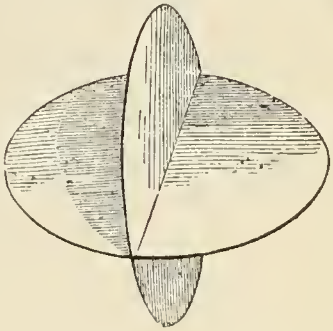


When so placed that they would never meet or cut each other, however far they might be extended.

[The two sides of a board, or two sheets of tin placed equidistant from each other at every point, represent parallel planes.]

34. *When are Planes said to be Perpendicular?*

PERPENDICULAR PLANES.

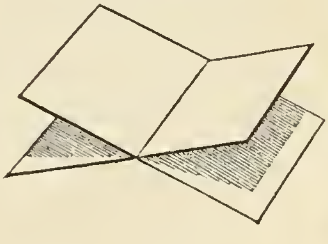


When one stands exactly *upright* upon the other; or when they cut each other at right angles.

[In the figure one plane is placed horizontally, and the other perpendicular to it. They are therefore perpendicular *to each other*, however they may stand in relation to the observer.]

35. *When are Planes said to be Inclined?*

INCLINED PLANES.



When they intersect or cut each other obliquely.

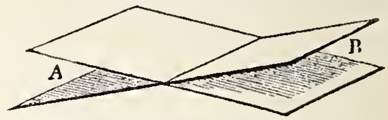
36. *What is meant by the Angle of Inclination?*

It is the angle contained be-

* A *plane surface* is to be distinguished from a *plane.*

tween the two surfaces of the planes nearest each other.

ANGLE OF INCLINATION.



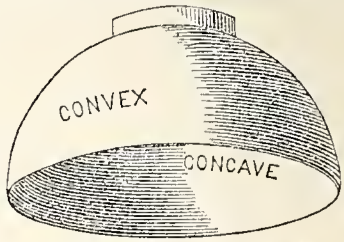
[The spaces A and B in the adjoining cut represent the Angle of Inclination.]

37. *What is meant by the Area* of a Plane Figure?*

It is the amount of surface contained therein.

38. *What is a Convex Surface?*

CONVEX AND CONCAVE SURFACES.



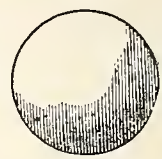
It is one that is swollen out like the outside of a bowl.

39. *Describe a Concave Surface.*

It is one that is hollowed out like the *inside* of a bowl.

40. *What is a Sphere?*

A SPHERE.



It is a *Globe* or *Ball*, every part of the surface of which is equidistant from a point within called its center.

[Hence the word *spherical*, or round, like a sphere.]

41. *What is a Hemisphere?*

HEMISPHERE.

It is the *half* of a sphere or globe.

[In Geography we often read of the Eastern and Western, and Northern and Southern hemispheres, but in Astronomy the term is only applied to the Northern and Southern portions of the heavens.]

42. *Describe a Spheroid.†*

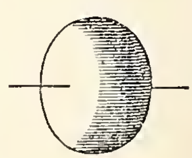
It is a body *resembling* a sphere, but yet not perfectly round or spherical.

43. *How many kinds of Spheroids are there?*

Two: the *Oblate* and the *Oblong*.

44. *What is an Oblate Spheroid?*

OBLATE SPHEROID.



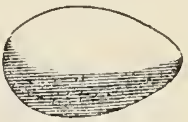
It is a globe that is slightly flattened, as if pressed on opposite sides.

[This is a very difficult figure to represent upon paper. Should the pupil fail to obtain a correct idea, the Teacher will be at no loss for an illustration.]

* A′-RE-A. † SPHE′-ROID.

45. *Describe an Oblong Spheroid.*

OBLONG SPHEROID.

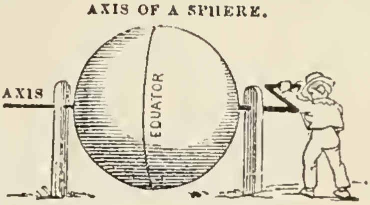


It is an elongated sphere.

[This figure, like an Oblate Spheroid, admits of various degrees of departure from the spherical form. It may be much or but slightly elongated, and the ends may be alike or otherwise. A common egg is an Oblong Spheroid.]

46. *What is meant by the Axis of a Sphere?*

AXIS OF A SPHERE.



It is the line, real or imaginary, around which it revolves.

[A wire run through the center of a round apple would represent the axis of a sphere.]

47. *What are the Poles of a Sphere.*

The extremities of its axis, or the points where the axis cuts the two opposite surfaces.

48. *Describe the Equator of a Sphere.*

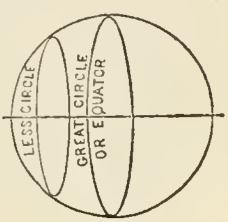
It is an imaginary circle upon its surface, midway between its poles, the plane of which cuts the axis perpendicularly, and divides the sphere into two equal parts or hemispheres.

49. *By what other name is the Equator of a Sphere sometimes designated?**

It is sometimes called a *Great Circle*, because no larger circle can be drawn upon a sphere.

50. *What is a Less Circle?*

GREAT AND LESS CIRCLES.



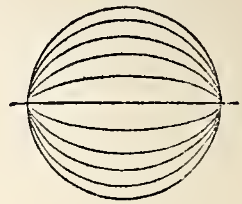
It is one that divides a sphere into two *unequal* parts.

[In the cut the circles are represented in perspective. The Great Circle embraces the *middle* of the sphere, where its full diameter is included; while the Less Circle passes around it between the Equator and the Poles, and is consequently "less" than the Equator. The subject of the Equator will be further illustrated in Lesson VI., where we speak of the Celestial and Terrestrial Spheres.]

* DES′-IG-NA-TED.

51. *What are the Meridians of a Sphere?*

MERIDIAN.



They are lines drawn from pole to pole *upon its surface.*

[Meridians all meet at the Poles, and are most distant at the Equator, as shown in the cut. Hence the length of a degree of *longitude* depends entirely upon the *latitude* of the place where it is measured. It varies from 69½ miles to nothing.]

LESSON IV.

OF LINES AND ANGLES.*

52. *What is a Point?*

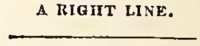
It is that which has no magnitude or extension, but simply position.

["The common notion of a point is derived from the extremity of some slender body, such as the extremity of a common sewing-needle. This being perceptible to the senses, is a *physical point*, and not a *mathematical point*; for, by the definition, a point has no magnitude."—PROFESSOR PERKINS.]

53. *What is a Straight or Right Line?*

It is the shortest distance between two points.

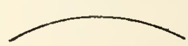
A RIGHT LINE.



54. *What is a Curve Line?*

It is one that departs continually from a direct course.

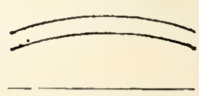
CURVE LINE.



55. *What are Parallel Lines?*

They are such as remain at the same distance from each other throughout their whole extent.

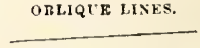
PARALLEL LINES.



56. *What are Oblique Lines?*

Such as are not parallel, but incline toward or approach each other.

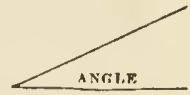
OBLIQUE LINES.



* The judicious Teacher will find it advantageous to make a free use of the Blackboard during this and the two following lessons.

57. *When two lines intersect each other, what is the space included between them called?*

AN ANGLE.



An *Angle.*

58. *How are Angles divided?*

Into *three kinds;* namely, the *Right Angle*, the *Acute*, and the *Obtuse.*

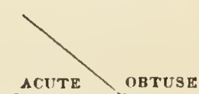
59. *What is a Right Angle?*

RIGHT ANGLES.

It is one formed when one straight line intersects another *perpendicularly.* The angles on each side are equal, and are Right Angles.

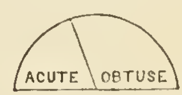
60. *What are Acute and Obtuse Angles?*

ACUTE AND OBTUSE ANGLES.

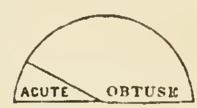


When one right line intersects another *obliquely*, the *smaller* angle is called an *acute* angle, and the larger an *obtuse* angle.

LARGE ACUTE ANGLE.



SMALL ACUTE ANGLE.



[An acute angle is always *less*, and an obtuse angle always *greater*, than a right angle. The former may include nearly one quarter, and the latter nearly one half of a circle. In the first of the adjoining figures the angles vary so slightly from right angles, that the *obtuseness* of the one and the *acuteness* of the other are hardly perceptible. In the other figure one angle is very obtuse, and the other very acute. So both these angles may vary to the amount of a quarter of a circle.]

61. *What is a Triangle?*

It is a plane figure, bounded by straight lines, and having only three sides.

62. *How many kinds of Triangles are there?*

Four: the *Equilateral*, *Isosceles*,* *Scalene*,† and *Right-Angled.*

63. *What is an Equilateral Triangle?*

AN EQUILATERAL TRIANGLE.

It is one having three sides equal.

[*Equilateral*, from the Latin *æquus*, equal, and *lateralis*, from *latus*, side.

* I-sos′-ce-les. † Sca-lene′.

64. *What is an Isosceles Triangle?*

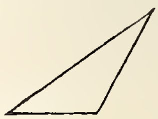
ISOSCELES TRIANGLE.

It is one having but two sides equal.

[The term *Isosceles* is from a Greek word, signifying *equal legs;* hence a triangle with two equal legs is called an Isosceles Triangle. Let the student carefully observe the derivation of these words, and he will never forget their meaning.]

65. *Describe a Scalene Triangle.*

SCALENE TRIANGLE.

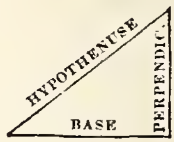


It is one having no two sides equal.

[The term *Scalene* is from the Greek *skalenos*, and signifies *oblique, unequal.*]

66. *What is a Right-Angled Triangle?*

RIGHT-ANGLED TRIANGLE.



It is one having *a right angle.*

67. *What are its different sides called respectively?*

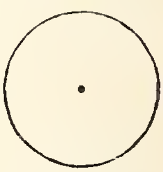
The *Base*, the *Perpendicular*, and the *Hypothenuse.**

LESSON V.

OF THE CIRCLE AND THE ELLIPSE.

68. *What is a Circle?*

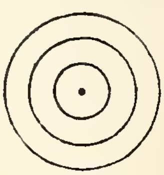
A CIRCLE



It is a plane figure, bounded by a curve line, every part of which is equally distant from a point within called the center.

69. *What are Concentric Circles?*

CONCENTRIC CIRCLES.



Such as are drawn *around a common center.*

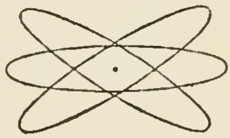
[If they are in the same plane they must be drawn *at different distances*, otherwise they could not constitute two distinct circles. If thus drawn they are *parallel*, otherwise they are not.]

---

* Hy-poth'-e-nuse, from a Greek word, which signifies to *subtend* or *stretch*: a line subtended (see 84) from the base to the perpendicular.

70. *Must all Concentric Circles be in the same plane?*

CONCENTRIC CIRCLES IN DIFFERENT PLANES.

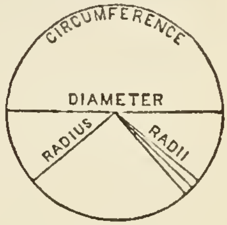


No: if drawn around the same common center they will be *concentric*, though they lie in different planes.

[Here the three circles are in different planes, but at the same distance. They are *concentric*, but not parallel.]

71. *What is the Circumference of a Circle?*

DIAMETER, CIRCUMFERENCE, ETC.



The curve line which bounds it.

72. *What is the Diameter?*

It is a right line passing through the center, and terminating each way in the circumference.

73. *Describe the Radius of a Circle.*

It is a right line drawn from its center to any point in the circumference.

[The plural of radius is *radii;* and as radii proceed from a common center, light, which proceeds from a luminous point in all directions, is said to *radiate;* and the light thus dispersed is sometimes called *radiations* or *radiance.*]

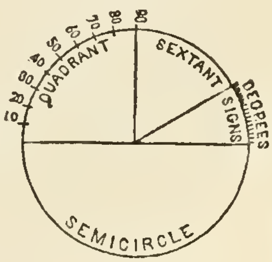
74. *How is the Circumference of a Circle divided?*

Into *Signs*, *Degrees*, *Minutes*, and *Seconds*.

[The student will probably recognize these divisions as what he has previously learned among his Arithmetical Tables, under the head of "Circular Measure."]

75. *What is a Sign?*

PARTS OF A CIRCLE.



The *twelfth part* of a circle.

76. *What is a Degree?*

The *30th part* of a *sign*, or the 360th part of a circle.

77. *What is a Minute?*

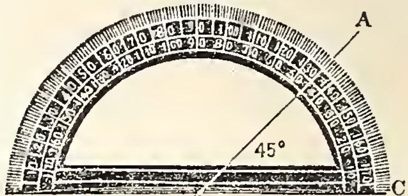
The 60th part of a degree, or the 21,600th part of a circle.

78. *What is a Second?*

The 60th part of a minute, or the 1,296,000th part of a circle.

[1. Thus all circles, whether great or small, are supposed to be divided into 360 equal parts called *degrees*, and marked thus, 360°. Each degree is again subdivided into 60 equal parts, called *minutes*, and each minute into 60 equal parts, called seconds. The minutes are marked thus, 60′, and the seconds thus, 60″.

A PROTRACTOR.



2. To save the trouble of dividing a circle into 360°, in order to measure the degrees of an angle, we make use of an instrument called a *Protractor*. It consists of a semicircle of silver or brass, divided into degrees, as represented in the inclosed figure. To measure an angle, as A, B, C, the straight edge of the protractor is placed upon the line B C, so that the center around which it is drawn will be exactly at the intersection of the lines, or point of the angle, as at B; then the number of degrees included between the lines on the protractor will represent the *quantity* or amount of the angle. From this it will be seen that the amount of the angle does not depend upon the length of the lines which form it, nor upon the magnitude of the circle on which the degrees are marked by which it is measured, but simply upon the width of the opening between the lines, as compared with the whole circumference around the point B. A circle marked off into degrees, minutes, and seconds, is called a *graduated circle*.]

79. *What other parts of a Circle can you mention?*

The *Semicircle*, *Quadrant*, *Sextant*, and *Arc*.

80. *What is a Semicircle?*

It is *one half* of a circle, and contains 180°.

81. *What is a Quadrant?*

It is the *fourth part* of a circle, and contains 90°.

[The term *Quadrant* is applied to a nautical instrument, of the form of a quarter of a circle, which is much used by navigators in determining the altitude or apparent height of the sun, moon, and stars.]

82. *Describe the Sextant.*

It is the *sixth* part of a circle, and contains only 60°.

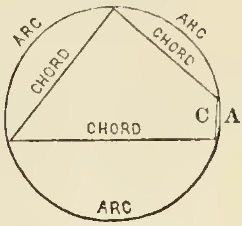
[The word *Sextant* also denotes an instrument similar to a Quadrant, and used for similar purposes. The main difference is, that one represents 60° and the other 90° of a circle. The *Octant*, or eighth part of a circle, is also used for similar purposes.]

83. *What is an Arc* of a Circle?*

It is any part of it less than a whole.

* From the Latin *arcus*, a bow, vault, or *arch*. By associating the word *arc* with *arch*, the student will always remember its meaning.

84. *What is a Chord?*

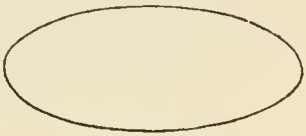


ARC AND CHORD.

It is a straight line within a circle, joining the extremities of an arc.

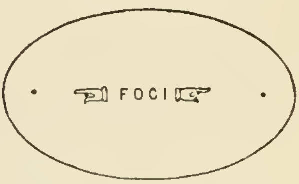
[The Chord of an Arc is said to be *subtended* (from *sub*, under, and *tendo*, to stretch), because it seems stretched under the arc like the string of a bow. In the cut there are four arcs and as many chords. The lower arc is a large one, while the arc and chord, A C, are quite small. Still each division of the circle, whether great or small, is an *arc*, and the line joining the extremities of each arc, respectively, is a *chord*.]

85. *What is an Ellipse?*


AN ELLIPSE.

It is an oblong figure, like an oblique view of a circle.

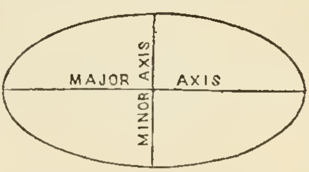
86. *In what respect does it differ from a Circle?*



FOCI OF AN ELLIPSE.

Its diameters are unequal; and it has two points called its *Foci*,* around which, as centers, the figure is described.

87. *How are the unequal diameters of an Ellipse distinguished?*

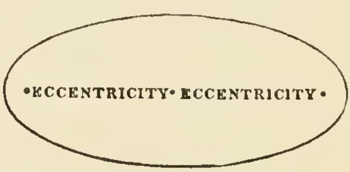


MAJOR AND MINOR AXES.†

The longer is called its *Major* and the shorter its *Minor* Axis.

[The longer is sometimes called the *Transverse* and the shorter the *Conjugate* Axis, but major and minor are more simple and perspicuous, and therefore preferable.]

88. *What is meant by the Eccentricity‡ of an Ellipse?*



ECCENTRICITY OF AN ELLIPSE.

It is the distance between the center and either focus.

[All circles drawn around two different points as centers are called *eccentric circles*.]

* Fo′-ci is the plural of *Fo-cus*. † Ax′-es is the plural of *Ax-is*.

‡ Ec-cen′-tric, *ex*, from, and *centrum*, center. Hence a circle that varies in its distance from the center is *eccentric*. So, also, persons who depart from the usual round of thought and custom are called *eccentric* persons.

LESSON VI.

THE TERRESTRIAL AND CELESTIAL SPHERES.

89. *Can you repeat the definition of a Sphere given in a preceding lesson?* (Question 40.)

90. *What then do you understand by a Terrestrial* Sphere?*

The Earth or Globe which we inhabit.

[Though the earth is not strictly speaking a *sphere*, as that figure is defined at 41, but rather an *oblate spheroid* (44), still it is usually called a *sphere*, on account of its near approach to that figure, and as a matter of convenience. A common artificial globe is a good representation of the terrestrial sphere.]

91. *What is the Axis of the Earth?*

The imaginary line about which it revolves (46).

92. *What are the Poles of the Earth?*

The extremities of her axis where they cut or pass through the earth's surface (47).

[The wire upon which an artificial globe turns represents the earth's axis, and the extremities the North and South Poles.]

93. *What is the Equator of the Earth?*

An imaginary circle drawn around it, from east to west, at an equal distance from each Pole, and dividing it into two equal parts, called Hemispheres (48).

[See definition and illustration, page 17.]

94. *What is Latitude?*

Distance North or South of the Equator.

95. *How is it reckoned?*

From the Equator each way, in Degrees, Minutes, and Seconds.

[As the distance from the Equator to the Pole cannot be more than a quarter of a circle, or 90°, it is obvious that no place can have more than 90° of latitude; or, in other words, all places upon the earth's surface must be between the Equator and 90° of latitude, either north or south.]

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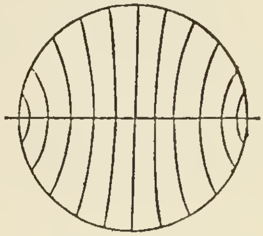
* Ter-res′-tri-al, from *terra*, the earth: pertaining to the earth. Hence St. Paul says, 1 Cor. xv. 40, "There are also celestial bodies, and bodies terrestrial; but the glory of the celestial is one, and the glory of the terrestrial is another.

PARALLELS.



96. *What are Parallels of Latitude?*

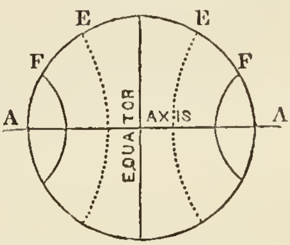
Circles either North or South of the Equator, and running parallel to it.

[We may imagine any conceivable number of parallels between the Equator and the Poles, though upon most maps and globes they are drawn only once for every ten degrees.]

97. *What are the Tropics?*

Two parallels of latitude, each 23° 28′ from the Equator.

THE TROPICS AND POLAR CIRCLE.



98. *What are they called respectively?*

The Northern is called the *Tropic of Cancer*, and the Southern the *Tropic of Capricorn.*

[1. The Tropical Circles are shown at E E in the annexed figure.

2. The sun never shines perpendicularly upon any points on the earth further from the Equator than the Tropics. Between these he seems to travel regularly, leaving the Southern Tropic on the 23d of December, crossing the Equator northward on the 20th of March, reaching the Northern Tropic on the 21st of June, crossing the Equator southward on the 23d of September, and reaching the Southern Tropic again on the 23d of December. In this manner he seems to cross and recross the Equator, and vibrate between the Tropics from year to year. The *cause* of this apparent motion of the sun will be explained in a subsequent lesson.]

99. *What are the Polar Circles?*

They are two parallels of latitude, 23° 28′ from the Poles. (See cut.)

100. *What are they called respectively?*

The *Northern* is called the *Arctic*, and the Southern the *Ant-arctic*, Circle.

[These circles are shown at F F in the preceding figure.]

101. *How do the Tropics and Polar Circles divide the surface of the Globe?*

Into five parts, called *Zones.*

[A *zone* properly signifies a *girdle;* but the term is here used in an accommodated sense, as only three of these five divisions at all resemble a girdle. The parts cut off by the polar circles are mere convex segments of the earth's surface.]

102. *How are these Zones classified?*

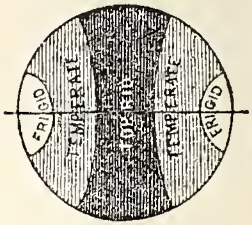
Into *Torrid*,* *Temperate*, and *Frigid*.†

103. *How many of each?*

One Torrid, two Temperate, and two Frigid.

104. *Where are they located, respectively?*

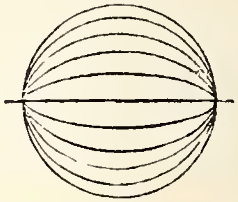
THE FIVE ZONES.



The torrid, *between the Tropics;* the temperate, between the Tropics and the Polar Circles; and the frigid, between the Polar Circles and the Poles.

105. *What are Meridians?*

MERIDIANS.



Imaginary lines drawn from Pole to Pole over the earth's surface.

[Meridians cross the Equator at right angles; and the plane of any two Meridians directly opposite each other would divide the earth into Eastern and Western Hemispheres, as the Equator divides it into Northern and Southern. We may imagine Meridians to pass through every conceivable point upon the earth's surface. They meet at the Poles, and are furthest apart at the Equator.]

106. *What is Longitude?*

It is distance East or West from any given Meridian.

107. *How is it reckoned?*

Both East and West, in Degrees, Minutes, and Seconds.

[A degree of longitude at the Equator comprises about 69½ miles, but is less and less as the meridians approach the Poles, at which points it is nothing. A degree of latitude is about 69½ miles on all parts of the globe.]

108. *What is the Meridian called from which we commence to reckon Longitude?*

The First Meridian.

[On European charts and globes longitude is usually reckoned from the Royal Observatory at Greenwich, near London; but in this country it is often reckoned from the Meridian of Washington. It would be better for science, however, if all nations reckoned longitude from the same Meridian, and all charts and globes were constructed accordingly.]

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* TOR'-RID, parched, dried with heat.

† FRIG'-ID, cold, wanting heat or warmth.

109. *What is the greatest Longitude that any place can have?*

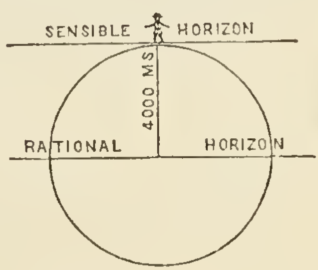
One hundred and eighty degrees (180°).

110. *What is meant by the Sensible Horizon?*

It is that circle which terminates our view, or where the earth and sky seem to meet.

111. *What is the Rational Horizon?*

It is an imaginary plane, below the visible horizon and parallel to it, which, passing through the earth's center, divides it into upper and lower hemispheres.



[1. These hemispheres are distinguished as *upper* and *lower* with reference to the observer only.

2. The sensible horizon is half the diameter of the earth, or about 4000 miles from the rational: and yet so distant are the stars that both these planes seem to cut the celestial arch at the same point; and we see the same hemisphere of stars above the sensible horizon of any place that we should if the upper half of the earth were removed, and we stood on the rational horizon of that place.]

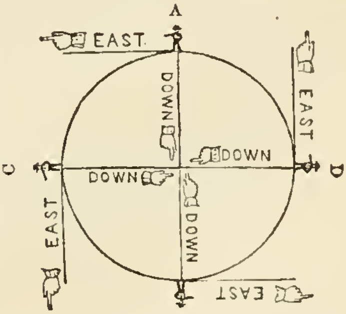
112. *What are the Zenith and Nadir Points?*

The *Zenith* is the point directly overhead, and the *Nadir* the point directly under our feet.

[1. These directions, it must be remembered, are merely *relative.* As the earth is a sphere, inhabited on all sides, the Zenith point is merely *opposite its center*, and the Nadir *toward its center.* So with the directions *Up* and *Down*: one is *from* the center, and the other *toward* it; and the same direction which is *up* to one is *down* to another. This fact should not merely be acknowledged, but should be dwelt upon until the mind has become familiarized to the conception of it, and divested, as far as possible, of the notion of an absolute up and down in space. We should remember that we are bound to the earth's surface by attraction, as so many needles would be bound to the surface of a spherical loadstone.

2. *East* and *West* also are not absolute, but merely relative directions. East is that direction in which the sun appears to rise, and West is the opposite direction; and yet, so far as absolute direction is concerned, what is East to one, as to the observer at A, is West to B, and so with C and D. And as the earth revolves upon its axis every twenty-four hours, it is obvious that East and West upon its surface must, in that time, change to every point in the whole circle of the heavens. The same is true of the Zenith and Nadir, or of up and down.]

UP AND DOWN, AND EAST AND WEST.



113. *What is meant by Space in Astronomy?*

It is the interval or void between the earth and the heavenly bodies, and extending onward beyond them all in every direction.

[Space has no limits, or, in other words, is *boundless* or *infinite.* Suppose six persons were to start from as many different points upon the earth's surface, as, for instance, one from each pole, and one from each of the positions occupied by observers in the next figure. Let them ascend or diverge from the earth in straight lines, perpendicularly to its surface; and though they were to proceed onward, separating from each other with the speed of lightning for millions of ages, none of these celestial voyagers would find an end to space, or any effectual barrier to hinder their advancement. Should they chance to meet another world in the line of their flight, it would soon be passed, like a ship met by a mariner upon the ocean, and beyond it *space* would still invite them onward to explore its immeasurable depths. And thus they might go on *forever*, without changing their position in respect to the *center* or *boundaries* of immensity; for as *eternity* has no beginning, middle, or end; so *space* is without center or circumference, an ethereal ocean, without bottom or shore.]

114. *What is the Celestial Sphere?*

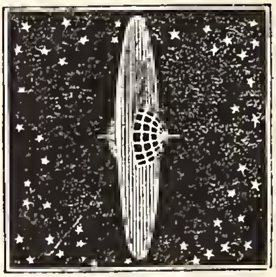
TERRESTRIAL AND CELESTIAL SPHERES.

It is the apparently concave surface of the heavens, in which the stars seem to be set, and which surrounds the globe on every side.

[The relation of the Terrestrial to the Celestial Sphere may be understood by the annexed diagram, in which the stars surround the earth in all directions, as they seem to fill the whole celestial vault.]

115. *What is the Equinoctial?*

THE EQINOCTIAL.



It is the *Celestial Equator*, or the plane of the earth's equator extended in every direction to the starry heavens.

116. *What is Declination?*

It is apparent distance either north or south of the Equinoctial.

[Declination is the same to the heavens that latitude is to the earth.]

117. *What is Right Ascension?*

It is distance east of a given point, and is reckoned on the Equinoctial quite around the heavens.

[In one respect Right Ascension in the heavens is like longitude on the earth: they are both reckoned upon the equators of their respective spheres; but while longitude is reckoned both east and west of the first meridian, and can only amount to 180°, Right Ascension is reckoned *only eastward*, and consequently may amount to 360°, or the whole circle of the heavens. The principal difference between Right Ascension and Celestial Longitude is, that the former is reckoned on the Equinoctial, and the latter on the Ecliptic.]

FIRST GRAND DIVISIONS OF THE UNIVERSE.

118. *What does the term Universe signify?*

The whole system of creation; or every thing visible and invisible in heaven and earth.

119. *How is the Universe divided?*

Into *Matter* and *Spirit.*

120. *What do you understand by Matter?*

It is any thing that you can *see* or *feel*, or that has *length*, *breadth*, and *thickness.*

[Of the *essence* or elements of matter we know nothing, our knowledge being confined entirely to its *properties.*]

121. *What is Spirit?*

It is that which learns, thinks, and reasons. It is the same as the intellect, mind, or soul.

[As with matter, so with spirit; we know it only by its properties or qualities.]

122. *How is Matter divided?*

Into *Animate* and *Inanimate.*

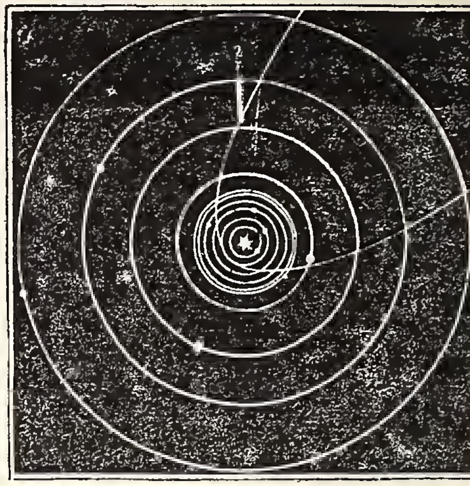
123. *Describe each.*

Inanimate matter has no *feeling* or *sensation*, like stones and trees; but animated matter has animal life, like the bodies of living men and beasts.

124. *To which division do the Heavenly Bodies belong?*

To that of inanimate matter.

THE SOLAR SYSTEM.



125. *What are the first grand divisions of the Heavenly Bodies?*

The SOLAR SYSTEM and the SIDEREAL HEAVENS.

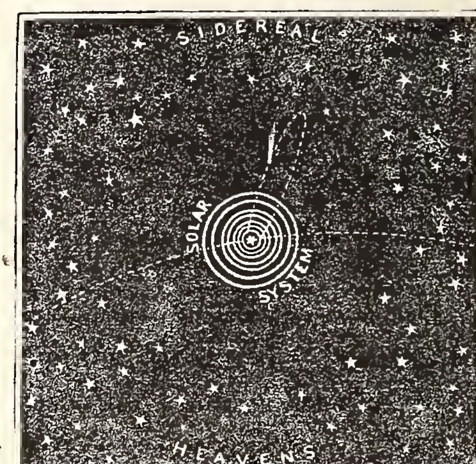
126. *What constitutes the Solar System?*

It includes the sun, and all the worlds that revolve around him.

[This system of worlds derives its name from the Latin term *Sol*, the Sun; hence the Solar System signifies *the System of the Sun.*]

127. *What do the Sidereal Heavens include?*

SOLAR SYSTEM AND SIDEREAL HEAVENS.



All those bodies that lie *around* and *beyond* the Solar System, in the region of the Fixed Stars.

[1. The word *Sidereal* is from the Latin *sideralis*, and signifies *pertaining to the stars.* The Sidereal Heavens are, therefore, the heavens of the fixed stars.

2. The relation of the Solar System to the Sidereal Heavens is shown in the annexed cut, where the sun appears only as a *star* at a distance from all others, and surrounded by his own retinue of worlds. The Solar System is drawn upon a small scale, and the Sidereal Heavens are seen around and at a distance from it in every direction.]

128. *What part of the book have you now gone over?*

PART FIRST, which consists of Preliminary Observations and Definitions.

129. *What do you enter upon in your next Lesson?*

PART SECOND, which treats of the *Solar System.*

PART II.

OF THE SOLAR SYSTEM.

LESSON VII.

BODIES THAT COMPOSE THE SYSTEM.

130. *Of what bodies does the Solar System consist?*

Of three classes; namely, the *Sun*, *Planets*, and *Comets.*

131. *How is the Sun distinguished?*

As the fixed center of the system, around which the other bodies revolve; and as the largest and only self-luminous body in the system.

132. *Describe the Planets.*

They are those large *globes* or *worlds* that revolve around the sun, and receive their light and heat from him.

[The term *Planet* signifies a *wanderer;* and is applied to some of the solar bodies, because they seem to wander or move about among the stars.]

133. *How are the Planets divided?*

Into *Primary* and *Secondary.*

134. *What are the Primary Planets?*

Such as revolve around the sun only, as their center of motion.

135. *What are the Secondaries?*

They are small planets that revolve around the Primaries, and accompany them in their revolution around the sun.

[The Secondary Planets may be seen near their respective Primaries in the cut, page 9. They are often called *Moons* or *Satellites.* A *satellite* is a *follower* or attendant upon another.]

136. *What is the Orbit of a Planet?*

It is the path it pursues in its revolution around the sun.

[The Orbits of the planets are represented by the white circles in the cut above referred to.]

137. *What do you understand by the* Interior *and* Exterior *Planets?*

The Interior are those whose orbits lie *within*, and the Exterior those whose orbits lie *without* the orbit of the earth.

[Some Astronomers speak of these two classes, respectively, as *Inferior* and *Superior*. The reason seems to be, that as those nearer the sun than the earth are *lower* than she is—that is, nearer the great center of the system—they are, in this respect, *inferior* to her; while, on the otber hand, those that are *above* or beyond her, are her *superiors*. But as the distinction is founded upon, and is intended to denote the *position* of the planets with respect to the earth's orbit, it is obvious that *interior* and *exterior* are the more appropriate terms. It seems hardly allowable to call the Asteroids superior planets, and Mercury and Venus, which are much larger, inferior.]

138. *What are the Asteroids?*

They are the twelve small planets revolving between the orbits of Mars and Jupiter.

[*Asteroid* signifies *star-like*, and is applied to these small planets because of their comparative minuteness. They are never seen except through telescopes, and through ordinary instruments are not always readily distinguished from the fixed stars.]

139. *What are Comets?*

They are a class of bodies distinguisbed for their long trains of light, their various shapes, and the great eccentricity (93) of their orbits.

[A Comet and part of its orbit are shown in the upper cut, page 30, to which the student is referred. In the miniature representation of the Solar System, on the same page, the whole of a Comet's orbit is exhibited.]

140. *Are the Planets and Comets self-luminous, or do they shine merely by reflection?*

They are all opake* bodies, and shine only as they are illuminated by the sun.

[That the planets and comets are opake, is obvious from the fact that the side toward the sun is all that ever looks bright, as is seen in the case of the new moon.

* O-PAKE', dark, obscure.

Hence the various *phases* or appearances of the planets. Again: whenever, by any means, the light of the sun is intercepted or cut off, the planet, thus deprived of its borrowed rays, ceases to shine. Hence what are called *Eclipses* of the Moon.]

LESSON VIII.

NAMES OF THE PLANETS, SIGNS, ETC.

141. *How many Primary Planets are there?*

Twenty-six.

[Fourteen of these have been discovered within a few years, and it is not improbable that there are several others, of the family of the Asteroids, that will hereafter be discovered. We speak of twenty-six as the number now known.]

142. *What are the Names of the Primary Planets?*

Beginning at the sun, and passing outward, they are:

MERCURY	☿	IRENE	
VENUS	♀	EUNOMIA	
EARTH	⊕	JUNO	⚵
MARS	♂	CERES	⚳
FLORA		PALLAS	⚴
CLIO		HYGEIA	
VESTA	⚶	MELPOMENE	
IRIS		MISILLIA	
METIS		ANONYMOUS	
HEBE		JUPITER	♃
PARTHENOPE		SATURN	♄
EGERIA		HERSCHEL	♅
ASTRÆA		NEPTUNE*	♆

[It is important for the student to commit these names to memory, in the order in which they here occur, as it will help to fix in his mind the *relative positions* of the planets, and greatly facilitate the acquisition of further knowledge respecting them.]

143. *After whom are the Planets named?*

After heathen gods and goddesses.

144. *Why is this?*

Because Astronomy was first studied by Pagan

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* This planet was first called *Le Verrier*, but is now more generally known by the name of *Neptune*.

nations, who named the planets then known after their imaginary divinities.

[A history of these fabulous beings is what is called *Mythology*.]

145. *Who was* MERCURY, *in Mythology?*

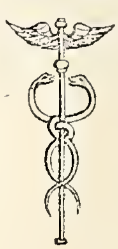
He was the messenger of the gods, and the patron of thieves and dishonest persons.

146. *What does his Astronomical Sign signify?*

It denotes his *caduceus* or *rod*, with serpents twined around it (☿).*

[1. Mercury was represented as very eloquent, and skillful in interpreting and explaining—as the god of rhetoricians and orators. Hence, when Paul and Barnabus visited Lystria, addressed the people, and wrought a miracle, they said, "The gods have come down to us in the likeness of men. And they called Barnabus Jupiter, and Paul *Mercurius, because he was the chief speaker.*" See Acts xiv. 8–13.

ROD OF MERCURY.



2. "The *caduceus* of Mercury was a sort of wand or scepter, borne by Mercury as an ensign of quality and office. On medals it is a symbol of good conduct, peace, and prosperity. The *rod* represents *power;* the *serpents, wisdom;* and the *two wings, diligence and activity.*"—ENCYCLOPÆDIA.

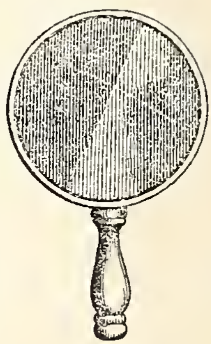
3. The original form of this sign may be understood by the annexed cut, to which the present astronomical symbol (☿) bears but a slight resemblance.]

147. *Who was* VENUS?

The Goddess of Beauty and Love.

148. *What is her Sign?*

MIRROR OF VENUS.



It is a *Mirror* or *Looking-glass*, which she is represented as carrying in her hand (♀).

[Anciently mirrors were made of *brass* or *silver*, highly polished, so as to reflect the image of whatever was brought before them. Hence it is said in the Book of Exodus, written fifteen centuries before Christ, that Moses "made the laver of *brass*, and the foot of it of *brass*, of the *looking-glasses* of the women," &c. For convenience, the ancient mirrors had a handle attached, as represented in the cut, which very much resembles the sign of the planet.]

* All these symbols should be drawn in rotation upon the Blackboard during recitation, by the Teacher or some member of the class. It will be well, therefore, for the student to observe each sign carefully, that he may be prepared to *draw* and *explain* it if called upon.

149. *What Sign represents the* EARTH?

She has two; one representing a sphere and its equator (⊖), and the other (⊕) the four quarters of the globe.

150. *Describe* MARS *and his Sign.*

Mars was the God of War, and his sign (♂) represents an ancient *shield* or *buckler*, crossed by a *spear*.

SPEAR AND SHIELD OF MARS.

[Gunpowder was not known to the ancients, so they had no pistols, muskets, or cannon. They fought with short swords and spears, and defended themselves with the *shield*, carried on the left arm. A shield and spear were, therefore, very appropriate emblems of war. The original form of the sign of Mars is presented in the cut.]

151. *Who was* FLORA?

The "Queen of all the Flowers." Sign ( ) a *rose*.

152. *Describe* VESTA *and her Sign.*

She was the Goddess of *Fire*, and her sign is an *altar* ( ), with a *fire* blazing upon it.

153. *Who was* IRIS?

The beautiful waiting-maid of Juno. Her sign ( ) is a *rainbow*, inclosing a *star*.

[It was the special office of *Iris* to stir up strife and discord among men, and to separate the soul and body of the dying.]

154. *Who was* METES?

The first wife of Jupiter, and the Goddess of Prudence and Sagacity. Sign ( ) an *eye* and *star*.

155. *Describe* HEBE *and her Sign.*

HEBE presided over children and youth, and was cup-bearer to Jupiter. Her sign ( ) is a *cup*.

[Hebe was celebrated for her beauty: but happening one day to stumble and spill the nectar, as she was serving Jupiter, she was turned into an *ostler*, and doomed to harness and drive the peacocks of the queen of heaven.]

156. *Who was* ASTRÆA, *and what is her Sign?*

She was the Goddess of Justice, with the sign of a *balance* (♎).

[1. Mythology taught that Justice left heaven, during the golden age, to reside on the earth; but, becoming weary with the iniquities of men, she returned to heaven, and commenced a constellation of stars. Virgo and Libra in the zodiac still represent the goddess Astræa and her golden scales.

2. The female figure, holding a pair of *scales*, in the coat of arms of several of the United States, is a representation of Astræa, and denotes *Justice*.]

157. *Describe* JUNO *and her Sign.*

She was the reputed Queen of Heaven; and her sign (⚵) is an ancient *mirror*, crowned with a star—an emblem of beauty and power.

158. *Describe* CERES *and her Sign.*

SICKLE OF CERES.

She was the Goddess of Grain and Harvest, and her sign (⚳) is a *sickle*.

159. *Describe* PALLAS *and her Sign.*

She was the Goddess of Wisdom and of War. She was represented as carrying a *spear*, which she brandished* terribly in time of battle; hence her sign (⚴) is *the head of a spear*.

160. *Who was* HYGEIA?

The Goddess of Health, and the daughter of Esculapius, the father of the healing art.

[Our modern word *Hygeian*, which signifies the laws of health, &c., is derived from the goddess Hygeia.]

161. *Who was* PARTHENOPE?

She was one of the three *Syrens*—a sea nymph† of rare beauty. They were all admirable *singers*; hence a *lyre*‡ ( ) is her appropriate sign.

[1. The three Syrens, Parthenope, Ligeia, and Leucosia, were represented as dwelling upon the coast of Sicily, and luring mariners upon the rocks of destruction by their enchanting songs. Hence whatever tends to entice or seduce to ruin, is often called a "syren song."

2. As this planet was discovered at the Naples Observatory, in Italy, it was quite appropriate to name it after one of the Syrens, that Mythology located on the coast of a neighboring island.]

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* BRAND'-ISH, to wave, shake, or flourish.

† NYMPH, a youthful goddess, inhabiting some particular locality.

‡ LYRE, a harp.

162. *After whom is* CLIO, *the last discovered Asteroid, named, and what is her Sign?*

After CLIO, one of the Muses. Her sign is a *star*, with a sprig of laurel over it (⚵).

163. *Who was* JUPITER?

He was the reputed father of the gods, and the King of Heaven.

164. *What does his Sign* (♃) *represent?*

It was originally the Greek letter ζ, *zeta*—the same as our Z—the initial of the Greek word *zeus*, the name for Jupiter.

165. *Describe* SATURN *and his Sign.*

OLD SATURN, OR CHRONOS.

SATURN, called by the Greeks *Chronos*, presided over *time* and *chronology*. He is represented as an old man, with wings, bald excepting a forelock, with a scythe in one hand and an hour-glass in the other. His sign (♄) represents a *scythe*.

[*Chro-nol'-o-gy* (from *chronos*, time, and *logos*, discourse); the science or method of computing time, keeping dates, &c.]

166. *How many names has* HERSCHEL?

Three.

167. *What are they?*

Georgium Sidus, *Uranus*, and *Herschel*.

168. *Why is it called* GEORGIUM SIDUS?

It was so called by its discoverer, in honor of George III. of England, who patronized or assisted him.

169. *What does* URANUS *signify?*

It is from *Urania*, the name of a heathen goddess, who was represented as presiding over *Astronomy*, or the study of the heavens.

[From this we have our word *uranography*, which signifies a description of the heavens.]

170. *Why is this planet ever called* HERSCHEL?

In honor of *Sir William Herschel*, its discoverer.

[Notwithstanding the importance of a uniform analogy in naming the planets, this one is more popularly known by the name of Herschel than by any other.]

171. *What, then, is the meaning of his Sign?*

It consists of the letter H, with a planet suspended from the cross-bar (♅), to indicate that Dr. Herschel was its discoverer.

172. *Describe* NEPTUNE *and his Sign.*

NEPTUNE was the god of the Seas, but the astronomical sign is composed of an L and a V united, with a planet suspended from the hair-line of the V (⯉) to indicate that Le Verrier was its discoverer.

173. *What Sign is generally used for the* MOON?

She is known by various representations, according as she is new, half-grown, or full; thus, ●, ◑, ○.

174. *What is the astronomical emblem of the* SUN?

It is a *shield* or *buckler*—☉, ☺, ☼.

[As the ancients often kept their bucklers bright, so as to dazzle the eyes of their enemies, this instrument was selected as an appropriate emblem of the Sun.]

LESSON IX.

DISTANCES OF THE PLANETS FROM THE SUN.

175. *Will you give the distances of the several Planets, in miles, commencing at the Sun?**

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* Where circumstances permit, and the Teacher is favorable to such exercises, these statistics may be learned to good advantage by concert recitations.

Mercury	37 millions.	Jupiter	495 millions.
Venus	69 "	Saturn	900 "
The Earth	95 "	Herschel	1,800 "
Mars	145 "	Le Verrier or Neptune	2,850 "
Asteroids, from 225 to 275 "			

[1. These distances, like most of the statistics throughout the book, are given in round numbers. The design is to impart a tolerably correct general idea, without overtasking the memory. The following cut will exhibit to the eye the

COMPARATIVE DISTANCES OF THE PLANETS.

2. To assist his conception of these vast distances, the student may imagine a railroad laid down from the sun to the orbit of Neptune. Now if the train proceed from the sun at the rate of thirty miles an hour, without intermission, it will reach *Mercury* in 152 years; the *Earth* in 361 years; *Jupiter* in 1,884 years; *Saturn* in 3,493 years; *Herschel* in 6,933; and *Neptune* in 10,800 years! Such a journey would be equal to riding 900,000 times across the continent, from Boston to Oregon!

3. It is now about 5,850 years since the creation of the world. Had a train of cars started from the sun at that time toward the orbit of Neptune, and traveled day and night ever since, it would still be 284 millions of miles within the orbit of Herschel—about where the head of the locomotive stands, as shown in the cut! To reach even that planet would require over 1,000 years longer, and to arrive at Neptune nearly 6,000 years to come!]

176. *What effect would it have upon the apparent magnitude of the Sun if we were to go to Mercury?*

He would appear much *larger*.

177. *Suppose we were to go out to Herschel or Neptune?*

He would appear much smaller.

178. *Why is this?*

Because the apparent magnitude of objects depends much upon the distance from which they are viewed.

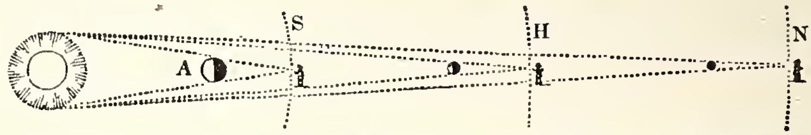
[1. This may be illustrated by the following cut, representing

NEAR AND REMOTE VIEWS OF THE SAME OBJECT.

Let A represent the position of an observer upon the earth, to whom the Sun appears 32′, or about half a degree in diameter. Now it is obvious that if the observer advance to B (half way), the object will fill an angle in his eye *twice as large* as it filled when viewed from A. Again: if he recede from A to C, the object will appear but *half* as large. Hence the rule, that the apparent magnitude is increased as the distance is diminished; and diminished as the distance is increased.

2. These principles are still further illustrated in the following cut, in which the observer is placed at three points, corresponding with the comparative distances of Saturn, Herschel, and Neptune.

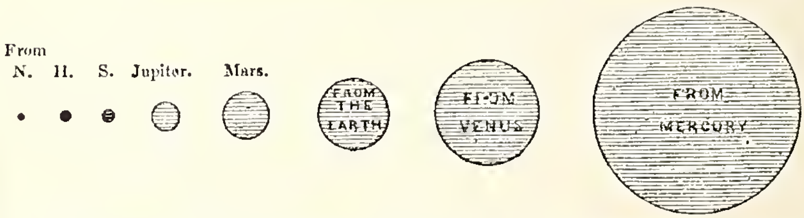
THE SUN VIEWED FROM DIFFERENT POINTS.



Here the first observer on the left stands upon *Saturn*, and the sun fills a comparatively large angle, as shown at A. From *Herschel* the angle is smaller, and at *Neptune* it is still less.

3. By applying the principles thus illustrated to the sun, as viewed from the several planets, we are enabled to determine his comparative magnitude, as seen from each of these points. The following cut represents the comparative apparent magnitude of

THE SUN AS SEEN FROM THE DIFFERENT PLANETS.



4. The relative apparent magnitude of the sun, as seen from different points in the Solar System, is as follows:

From Mercury	$82\frac{1}{2}'$	From Jupiter	$6'$
" Venus	$44\frac{1}{3}'$	" Saturn	$3\frac{1}{3}'$
" Earth	$32'$	" Herschel	$1\frac{2}{3}'$
" Mars	$21'$	" Neptune	$50''$
" The Asteroids, say	$12'$		

5. Let us continue our imaginary journey outward, beyond Neptune, toward the fixed stars, and in a short time the glorious sun, so resplendent and dazzling to our view, will appear only as a sparkling *star;* and the fixed stars will expand to view as we approach them, till they assume all the magnitude and splendor of the sun himself.]

LESSON X.

LIGHT AND HEAT OF THE PLANETS.

173. *From what source are the Light and Heat of the Planets derived?*

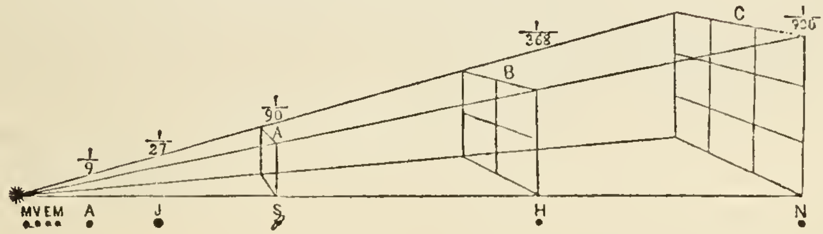
From the Sun.

180. *What effect does the variation in their distances have upon them, in this respect?*

It must make a great difference in their respective *temperatures.*

[1. The following cut is designed to illustrate the

PHILOSOPHY OF THE DIFFUSION OF LIGHT.



Here the light is seen passing in straight lines, from the sun on the left toward the several planets on the right. It is also shown that A, B, and C receive equal quantities of light, though B is four times and C nine times as large as A; and as the light falling upon A is spread over four times as much surface at B, and nine times as much at C, it follows that it is only one-ninth as intense at C, and one-fourth at B as it is at A. Hence the rule, that *the light and heat of the planets is, inversely, as the squares of their respective distances.*

2. The student may not exactly understand this last statement. The square of any number is its product when multiplied by itself. Now suppose we call the distances A, B, and C, 1, 2, and 3 miles. Then the square of 1 is 1; the square of 2 is 4; and the square of 3 is 9. The light and heat, then, would be in *inverse* proportion at these three points, as 1, 4, and 9; that is, four times less at B than at A, and nine times less at C. These amounts we should state as 1, $\frac{1}{4}$, and $\frac{1}{9}$.]

181. *What is the comparative Light and Heat of the planet Mercury?*

It must be about $6\frac{1}{2}$ times as great as that of our globe.

182. *How high a Temperature would that be?*

About 325 degrees, or 113° hotter than boiling water.

[Taking the average temperature of our globe at 50 degrees, that of Mercury would be $6\frac{1}{2}$ times 50, or 325. But water boils near the level of the sea at 212, and this being subtracted from 325, leaves 113 degrees.]

183. *What, then, must be the Light and Temperature of Neptune?*

Only about $\frac{1}{900}$ part as great as that of our globe.

[1. The comparative light and heat of the planets, the earth being 1, is as follows:

Mercury	$6\frac{1}{2}$	Jupiter	$\frac{1}{27}$
Venus	2	Saturn	$\frac{1}{90}$
The Earth	1	Herschel	$\frac{1}{368}$
Mars	$\frac{1}{2}$	Neptune	$\frac{1}{900}$
The Asteroids	$\frac{1}{8}$		

These last are degrees of coldness of which we can form no just conception.

2. It is not certain, however, that the heat is proportionate to the light received by the respective planets, as various local causes may conspire to modify either extreme of the high or low temperatures. For instance, Mercury may have an atmosphere that arrests the light, and screens the body of the planet from the insupportable rays of the sun; while the atmospheres of Saturn, Herschel, &c., may act as a refracting medium to gather the light for a great distance around them, and concentrate it upon their otherwise cold and dark bosoms.]

LESSON XI.

MAGNITUDE, DENSITY, AND GRAVITATION OF THE PLANETS.

184. *What is meant by the Magnitude of a planet?*

Its size, bulk, or dimensions.

185. *What is the Diameter of a planet?* (See 72.)

186. *State the Diameter of the several planets, so far as known.*

	Miles.		Miles.
Mercury	2,950	Irene	
Venus	7.900	Eunomia	
Earth	7,912	Juno	1,400
Mars	4,500	Ceres	163
Flora		Pallas	770
Clio		Hygeia	
Vesta	295	Melpomene	
Iris		Missillia	
Metis		Anonymous	
Hebe		Jupiter	89,000
Parthenope		Saturn	79,000
Egeria		Herschel	35,000
Astræa		Neptune	31,000

187. *What is the bulk of Mercury as compared with our globe?*

He is about $\frac{1}{16}$th as large.

188. *What is the comparative size of Venus?*

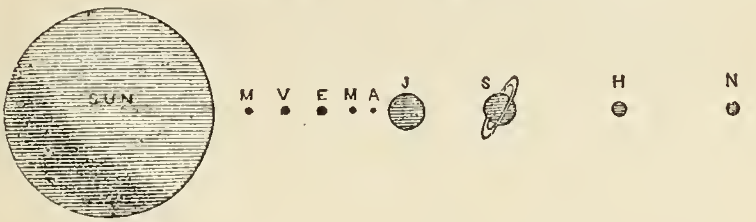
About $\frac{9}{10}$ that of the Earth.

189. *How do Jupiter, Saturn, Herschel, and Neptune compare with our globe?*

Jupiter is more than 1,400 times as large; Saturn 1,000 times; and Herschel and Neptune each 90 times.

[This subject may be illustrated by the following cut, exhibiting the

COMPARATIVE MAGNITUDE OF THE SUN AND PLANETS.



The student may think it almost incredible that what appears only as a *star* in the heavens should be larger than the mighty globe upon which he dwells; but when he considers their immense *distance*, and remembers the effect it must have upon their apparent magnitude, as illustrated under Question 178, he will see that they could not be seen at all if they were not very large bodies.]

DENSITY.

190. *What is meant by Density?*

Compactness or closeness of parts.

[1. For example, *cork* is less dense than iron, and stone is more dense than common earth.

2. *Density* and *solidity* are not the same; for while *ice* is more solid than lead, it is far less dense, and is consequently lighter.]

191. *What can you say of the Density of the planets?*

They differ in the compactness of the substances of which they are composed.

192. *What is the Density of Mercury?*

About the same as *lead*, or three times the average density of our globe.

193. *State the Density of Venus and Mars.*

It is about the same as that of the Earth.

194. *How is it with the other large planets?*

Jupiter and Herschel have but $\frac{1}{4}$ and Saturn $\frac{1}{10}$ the density of our globe; the first two answering to *water*, and the latter to *cork*.

GRAVITATION.

195. *What is Gravitation?*

The tendency of all bodies toward each other.

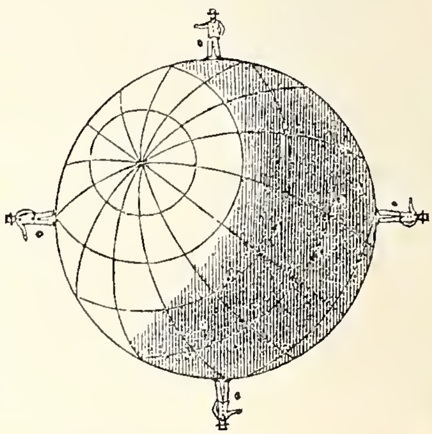
[Gravitation is a species of *attraction*, and is often called attraction, or the attraction of gravitation.]

196. *Give an example of the effect of Gravitation.*

It is seen when bodies raised from the earth, and left without support, fall to its surface.

[All substances fall toward the earth's center from every part of the globe, as a spherical loadstone would attract particles of steel to its surface in every direction. Hence when these four men, standing on different sides of the globe, drop each a stone, they all fall toward the same point, because the earth attracts them all to herself.]

ATTRACTION OF THE EARTH.



197. *What constitutes the Weight of any substance?*

It is the force of attraction or gravitation.

198. *Upon what does the amount of this force depend?*

Upon the quantity of matter* in the bodies attracting, and their distances from each other.

199. *Why does not a cubic foot of cork weigh as much as a cubic foot of lead?*

Because, being much less dense, it contains much less matter to be attracted.

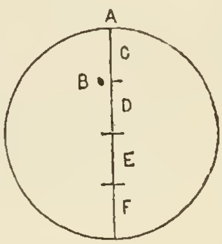
* Matter, in philosophy, signifies any visible or tangible substance—as earth, wood, stone, water, &c.

200. *Suppose the Earth was only half as dense as she is, how would it affect the weight of bodies at her surface?*

It would be reduced one-half.

201. *Suppose a stone, weighing four pounds at the Earth's surface, were taken down half way to her center, what would it weigh there?**

About two pounds.



[In this cut the diameter of the earth is divided into four equal parts, C, D, E, and F. At A the whole attraction amounts to four pounds. When the stone reaches B, the part C attracts as strongly upward as D does downward, and their forces balance each other. Then as C and D mutually neutralize each other, we have only the parts E and F, or one-half the globe to attract the stone downward; consequently the attractive force would be only half as great at B as at A, and the stone would weigh only two pounds.]

202. *What would it weigh at the Earth's center?*

Nothing.

203. *Why?*

Because the attractive force would be the same in all directions.

204. *Would an object weigh the same on the surface of the several planets?*

It would not.

[It is intended merely to assert that the attractive force is not the same. If a body were actually weighed upon the surface of each planet, by scales, it would weigh the same on all; because the force of attraction upon the *weights* would be just equal to that of the body to be weighed, whether it were more or less. With a steelyard it would be the same. A spring and hook, therefore, is the only instrument with which we could weigh objects accurately on all the planets.]

205. *Why not?*

Because they vary in *bulk* and *density*, and consequently in their attractive forces.

[1. A body weighing one pound on the Earth would weigh $9\frac{1}{2}$ oz. on Mercury, 15 oz. on Venus, 8 oz. on Mars, 2 lbs. 8 oz. on Jupiter, 1 lb. $5\frac{1}{4}$ oz. on Saturn, and about $12\frac{1}{2}$ oz. on Herschel.

2. A person weighing 150 lbs. on the Earth, would consequently weigh 75 lbs. on

* This question proceeds upon the supposition that a well be sunk 2,000 miles deep without filling with water.

Mars, 375 on Jupiter, &c. The attractive force of the Asteroids is so slight, that if a man of ordinary muscular strength were transported to one of them, he could probably lift a hogshead of lead from its surface without difficulty.

3. In estimating the attractive force of a planet, we must consider both its *bulk* and *density*. Though one planet were as large again as another, still if it were but half as dense, it would contain no more matter than the smaller one; and their attractive force would be equal. If Jupiter, for instance, were as dense as the earth, his attractive force would be four times what it now is; and if the density of all the solar bodies were precisely the same, their attractive force, or the weight of bodies on their surfaces, would be in exact proportion to their bulk.]

206. *How does Distance affect the attractive force of bodies?*

The rule upon this subject is, that *the attraction is in inverse proportion to the square of the distance.*

[If this should not be easily understood by the pupil, he may turn back to Question 180 and the Note. Light and gravitation are governed by precisely the same law, so far as the effect of distance upon them is concerned; so that the illustration of one, as given at page 41, will answer for both.]

207. *Suppose three bodies, whose distances from the Sun were as* 1, 4, *and* 8, *what would be their relative attraction?*

1, $\frac{1}{16}$, and $\frac{1}{64}$.

LESSON XII.

REVOLUTIONS OF THE PLANETS AROUND THE SUN.

208. *Are the planets at rest or in motion?*

They are all in motion, or revolution.

209. *Describe their motions.*

Each planet has two revolutions: one around the Sun, called its *Periodical** revolution; and another on its own axis, called its *Diurnal†* revolution.

210. *What is the time required for a planet to revolve around the Sun called?*

Its *Periodic Time.*

---

* PE-RI-OD'-IC-AL, occurring at regular intervals, or at stated times; hence weekly, monthly, or quarterly publications are called *Periodicals.*

† DI-URN'-AL, from the Latin *diurnus,* daily.

211. *In what direction do the planets revolve around the Sun?*

Eastward, or toward that part of the heavens in which the Sun appears to rise.

212. *Can you state the Periodic Times of the several planets?*

Mercury	0 yrs. 88 ds.	Jupiter............	11 yrs. 317 ds.
Venus...............	0 " 225 "	Saturn..............	29 " 175 "
The Earth	1 or 365¼ "	Herschel...........	84 "
Mars..................	1 yr. 322 "	Neptune	164 "
The Asteroids about	4½ "		

[As the periodic time of a planet constitutes its *year*, it follows that Herschel's year equals 84 of ours, &c.]

213. *What is the hourly motion of the planets in their orbits?*

From 11,000 to 110,000 miles.

214. *Which have the most rapid motion?*

Those nearest the Sun.

215. *What is the hourly motion of the Earth?*

About 68,000 miles.

[1. It may seem incredible to the student that the ponderous globe is flying through space at the rate of 68,000 miles an hour, or some 30 times as swift as a bullet; but, like many other astonishing facts in Astronomy, its truth can easily be demonstrated. The diameter of a circle is to its circumference as 7 is to 22 nearly. The Earth's distance from the Sun being 95,000,000 miles (Question 175), it is obvious that the whole diameter of her orbit is twice that distance, or 190,000,000; then, as 7 : 22 :: 190,000,000 to 597,142,857 miles, the circumference of the Earth's orbit. Divide this sum by 8.766, the number of hours in a year, and we have 68,108 miles as the hourly velocity of the Earth.

2. As the Earth is not propelled by machinery like a steamboat, or borne upon wheels like a railroad car, it is not strange that we are insensible of its rapid motion, especially as every thing upon its surface, and the atmosphere by which it is surrounded, move onward with it in its rapid flight.]

216. *What keeps the planets revolving so steadily in their orbits?*

It is the result of two distinct influences, called the *centripetal** and *centrifugal†* forces.

* CEN-TRIP'-E-TAL, from *centrum*, center, and *peto*, to move toward: tending to the center.

† CEN-TRIF'-U GAL, from *centrum*, and *fugio:* to fly from the center.

☞ In the above two cases we agree with Dr. Webster, that "the common accentuation is artificial and harsh. The accent on the first and third syllables, as in *Circumpolar*, would be natural and easy."

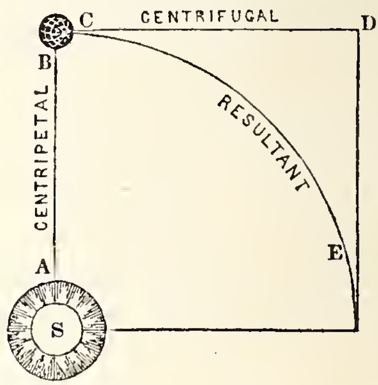
217. *What is the Centripetal Force?*

It is the mutual attraction of the Sun and planets, which prevents them from wandering off from the Sun.

218. *Describe the Centrifugal Force.*

It is the tendency to fly off from the Sun, produced by the planets revolving around him.

CENTRIPETAL AND CENTRIFUGAL FORCES.



[1. In the cut we have an arc of the Earth's orbit. The attraction of the sun, shown by the line A B, is the *centripetal* force, while the tendency to depart from the sun is the *centrifugal force*. The two combining, give the planet what may be called a *resultant* motion, in the direction C E; and as it meets no resistance in the void of space, it continues to revolve from age to age.

2. If the centrifugal force were suspended, the planets would at once fall to the Sun; and if the centripetal force were destroyed, the planets would fly off in straight lines, and leave the Solar System forever.

Then might be realized the chaos and confusion of the poet:

"Let Earth unbalanced from her orbit fly,
Planets and suns run lawless through the sky,
Let ruling angels from their spheres be hurled,
Being on being wreck'd, and world on world."]

219. *Why do the planets nearest the Sun revolve most rapidly?*

Because the nearer the Sun the greater the attraction (206), and the more centrifugal force is necessary to balance it.

[The mechanism of the Solar System strikingly displays the wisdom of the great Creator. The centrifugal force depends, of course, upon the rapidity of the revolution; and in order that these forces might be exactly balanced, God has imparted to each planet a velocity just sufficient to produce a centrifugal force equal to that of its gravitation. Thus they neither fall to the Sun on the one hand, nor fly off beyond the reach of his beams on the other, but remain balanced in their orbits between these two great forces, and steadily revolving from age to age.]

220. *What three great principles or laws are found to prevail throughout the Solar System?*

The first is, that *all the planets and comets revolve in elliptical orbits.*

221. *State the Second law of planetary motion.*

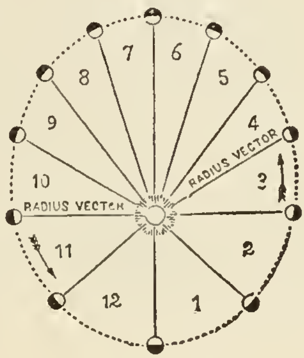
The *Radius Vector of a planet describes equal areas in equal times.*

222. *What is meant by the Radius Vector?**

It is an imaginary line joining the center of the Sun and the center of the planet, in any part of its orbit.

[In the cut, the lines extending from the Sun to the planet at different points, represent the *radius vector* in different positions.]

RADIUS VECTOR.



223. *What is meant by the Radius Vector describing equal areas in equal times?*

That it sweeps over the same surface in an hour, when a planet is near the Sun and moves swiftly, as when it is furthest from the Sun and moves most slowly.

[In the preceding cut the twelve triangles, numbered 1, 2, 3, &c., over each of which the radius vector sweeps in equal times, are equal.]

224. *What is the Third great law?*

That *the squares of the periodic times of any two planets are proportioned to the cubes of their mean distances from the Sun.*

[1. The student will understand that the *square* of any number is the product of that number multiplied by itself; and the *cube* of a number is the result when that number is multiplied by itself, and the product multiplied by the same number again.

2. By this law of proportion between the periodic times and the average distances of the planets, when one is ascertained the other can be deduced from it.]

225. *Who discovered these three great laws?*

Kepler, a German astronomer, after whom they are called *Kepler's Laws.*

[*Kepler* was a disciple of *Tycho Brahe*, a noted astronomer of Denmark, and was equally celebrated with his renowned tutor. His residence and observatory were at Wirtemburgh, in Germany.]

* VEC'-TOR, from *veho*, to carry:—a radius carried around.

LESSON XIII.

ASPECTS, SIDEREAL AND SYNODIC REVOLUTIONS, ETC.

226. *What is meant by the Aspects of the planets?*

Their positions with reference to each other.

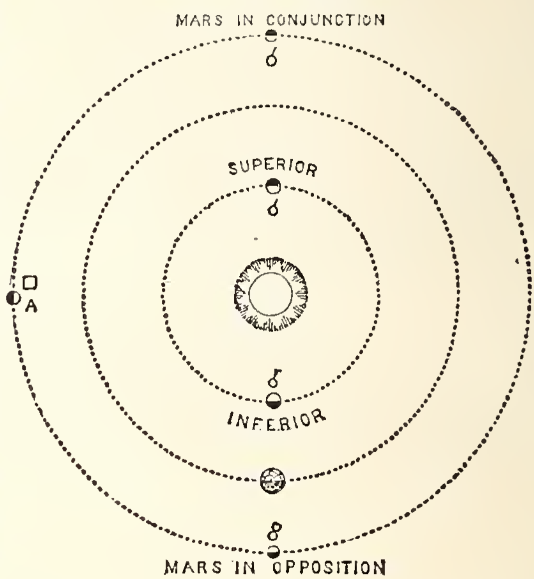
227. *When are planets said to be in Conjunction?*

When they are in the same longitude in the heavens.

[1. If they are on the same meridian, or, in other words, are the same distance east or west, they are in the same longitude, and are said to be in conjunction.

2. In this cut the Sun, Venus, and Mars are shown in conjunction; being, as viewed from the Earth, in the same longitude. The following is the sign of conjunction ☌.]

ASPECTS OF THE PLANETS.



228. *What is an Inferior Conjunction?*

It is when the planet is between the Earth and the Sun. (See Venus at "inferior" in the cut.)

[This conjunction is called *inferior*, because the dark side of the planet is toward the Earth, and she shines with inferior brilliancy.]

229. *What is a Superior Conjunction?*

It is when a planet is *beyond* the Sun, and its illuminated side is toward us. (See Venus at "superior.")

230. *When are planets in Quadrature?*

When they are 90° apart.

[Mars would be in quadrature with the Earth and Venus in the above figure, if placed at A. The sign for quadrature is □ as there represented.]

231. *When are planets in Opposition?*

When in opposite directions in the heavens, one *toward* and the other *from* the Sun.

[In the lower part of the last cut Mars and Venus are in opposition. This aspect is denoted by the sign ☍, as there shown.]

232. *What is meant by the Sidereal Revolution of a planet?*

It is a complete revolution from any given point in its orbit around to the same point again.

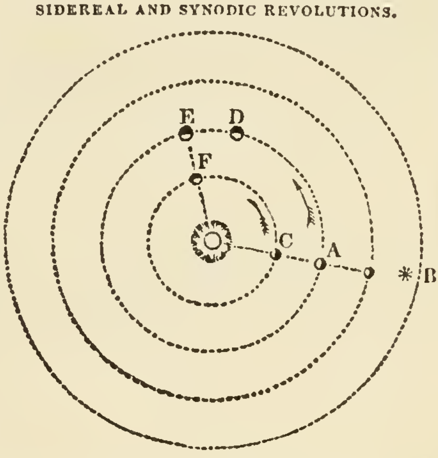
233. *Why is it called a Sidereal Revolution?*

From *sideralis*,* because such complete revolution is determined by observations upon the fixed stars.

234. *What is a Synodic Revolution?*

It is from one conjunction to the same conjunction again.

SIDEREAL AND SYNODIC REVOLUTIONS.



[1. In the adjoining cut the revolution of the Earth from A, opposite the star B, around to the same point again, would be a *sidereal* revolution.

2. Suppose the Earth and Mercury to start together from the points A C (where Mercury would be in inferior conjunction with the Sun), and to proceed in the direction of the arrows. In 88 days Mercury would come around to the same point again; but as the Earth requires more than four times that number of days for a revolution, she will only have reached the point D when Mercury arrives at C again; so that they will not be in conjunction, and a synodic revolution will not be completed by Mercury. He starts on, however, in *his* second round, and constantly gaining upon the Earth, till in 27 days from the time he left C the second time, he overtakes the Earth at E and F, and is again in inferior conjunction.

3. From this illustration, it will be seen that the synodic revolution of a planet must always require more time than the sidereal.

4. The term *synod* signifies a *meeting* or *convention;* and the synodical revolution of a planet is a *meeting* revolution; that is, from one meeting or conjunction to another. By noting the synodic as a *meeting* revolution, its meaning will not be forgotten.]

235. *Which requires the most time, the Sidereal or the Synodic Revolution?*

The synodic.

* See Question 127 and Notes.

236. *What familiar illustration can you give?*

At twelve o'clock the hour and minute-hands of a clock or watch are together; but at one o'clock, when the minute-hand has made a complete revolution, and points to XII. again, the hour-hand has gone forward to I., and the minute-hand will not overtake it till about five minutes afterward.

237. *Which revolution, then, represents the Sidereal and which the Synodic?*

The revolution of the minute-hand from XII. to XII again, is like the *sidereal* revolution of a planet; and when it overtakes the hour-hand, it becomes a *synodic* revolution.

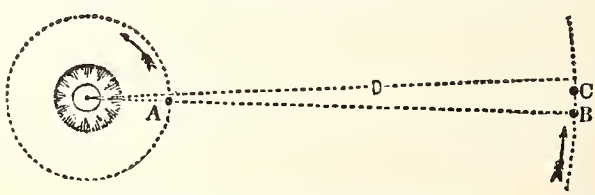
238. *State both the Sidereal and Synodic periods of some of the planets.*

	Sidereal.		Synodic.
Mercury		88 days	115 days.
Venus		225 "	594 "
Mars	1 year,	322 "	780 "
Jupiter	11 "	317 "	399 "
Saturn	29 "	175 "	378 "
Herschel	84 "		369½ "
Neptune	164 "		367½ "

239. *Why is the Synodic period of the most distant planet the nearest to the periodic time of the Earth?*

Because, being remote from the Sun, they move very slowly, and the Earth soon overtakes them after performing her periodic revolution.

SYNODIC PERIODS OF THE EXTERIOR PLANETS.



[Suppose the Earth and Herschel to be in conjunction, as shown at A B. In 365¼ days the Earth performs her sidereal or periodic revolution, and returns to the point A again. In the mean time Herschel, whose periodic time is 84 years, has passed through only $\frac{1}{84}$th part of his orbit, or about 4¼° to the point C; and in 4½ days the Earth overtakes him on the line D. It is on this account that the synodic period of Herschel is only 367½ days; or 4¼ days longer than the periodic time of the Earth.]

LESSON XIV.

DIRECT AND RETROGRADE MOTIONS, PLANETS STATIONARY, ETC.

240. *When is a planet's motion said to be Direct?*

When it is *eastward* among the stars.

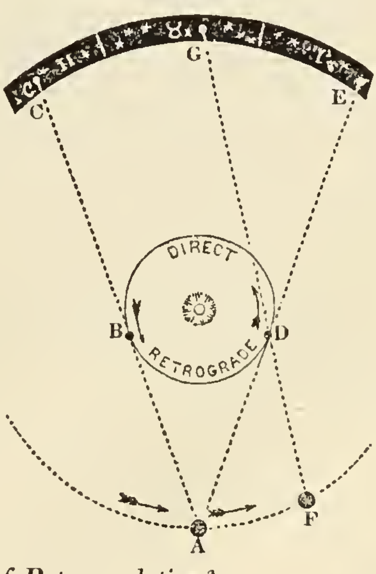
[All the planets actually revolve eastward, as stated at 211, and they generally *appear* thus to revolve, though not always.]

241. *When is a planet said to Retrograde?*

When it seems to go back or *westward* in the ecliptic.

242. *What is the cause of this apparent variation in the course of the planets?*

DIRECT AND RETROGRADE MOTIONS.



It is due to the rapid revolution of the interior planets around the Sun, and to the changes in the position from which we view them, produced by the Earth's revolution.

[Suppose the Earth to be at A and Venus at B, she would appear to be at C, among the stars. If the Earth remained at A while Venus was passing from B to D, she would seem to retrograde from C to E: but as the Earth passes from A to F while Venus goes from B to D, Venus will appear to be at G; and the amount of her apparent westward motion will only be from C to G.]

243. *What is meant by the Arc of Retrogradation?*

It is the portion of the ecliptic through which a planet seems to retrograde.

[In the preceding figure it would be the arc C G.]

244. *When is a planet said to be Stationary?*

When it appears to move neither east nor west among the stars.

[1. For a short time, when Venus is at B, she will be coming *toward* the Earth, and at D she will be going *from* the Earth; so that she will appear to remain *stationary* at C and E.

2. Some late writers have called this a *stationary motion*; for instance, one asks, "When is a planet's *motion* said to be *stationary?*" We were not before aware that *no motion at all* was a *stationary* motion. See Clark's Astronomy, p. 15, and Smith's Illustrated, p. 12.]

245. *What is meant by the greatest Eastern and Western Elongations of a planet?*

It is the greatest apparent distance east or west of the Sun at which it is ever found.

[In the last cut the point B would represent the greatest *eastern* and D the greatest *western* elongation of Venus.]

246. *What is the greatest angular distance to which Venus ever departs from the Sun?*

She varies from 45 to 48 degrees.

247. *What does this variation in her elongations indicate?*

That she revolves in an elliptical orbit.

[1. It will be obvious, without illustration, that if she is further from the Sun at one time than at another (as is evident from the difference in her elongations), she cannot revolve in a circle, and her orbit must be elliptical.

2. The eccentricity of her orbit is ascertained by observing the difference between her greatest and least distance, which is only about 3°. Her orbit, therefore, is very nearly a circle.]

248. *When is Venus Morning Star?*

When she is *west* of the Sun, and rises before him.

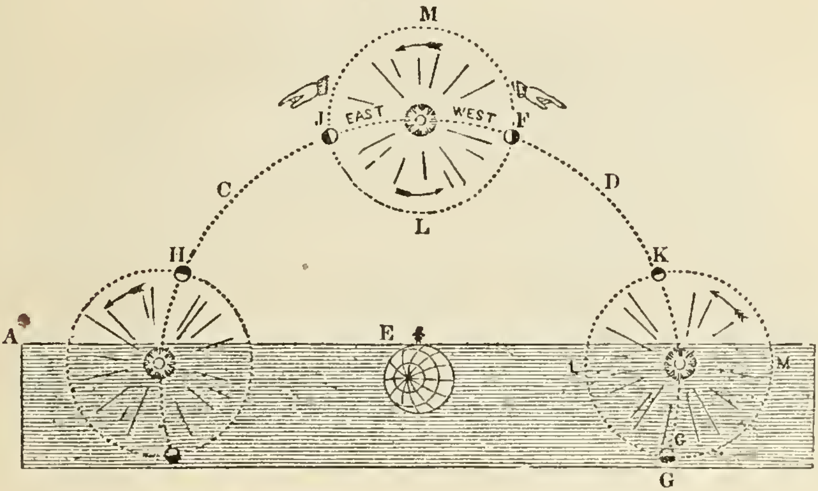
[She must be *west* of the Sun, of course, from her inferior to her superior conjunction. See cut, page 50.]

249. *When is she Evening Star?*

When she is *east* of the Sun, and remains above the horizon after he has gone down.

[From her superior to her inferior conjunction she is east of the Sun, and Morning Star.]

VENUS AS MORNING AND EVENING STAR.



[Let the student hold the book up *south* of him, and he will at once see why Venus is alternately Morning and Evening Star. Let the plane A B represent the sensible or visible horizon, C D the apparent daily path of the Sun through the heavens, and E the Earth in her apparent position. The Sun is shown at three different points; namely, rising in the east; on the meridian; and setting in the west: while Venus is seen revolving around him from west to east, or in the direction of the arrows. Now it is obvious that when Venus is at F, or *west* of the Sun, she sets before him as at G, and rises before him as at H. She must, therefore, be *Morning Star.* On the other hand, when she is *east* of the Sun, as at J, she lingers in the west after the Sun has gone down, as at K, and is consequently *Evening Star.*

2. In this cut, Venus would be at her greatest elongation *eastward* at J, and *westward* at F; and in both cases would be "*stationary.*" At L and M she would be in *conjunction* with the Sun.

3. Were the Earth to suspend her daily rotation, with the Sun on the meridian of the observer, as represented at L, we might readily watch Venus through her whole circuit around the Sun.

4. Venus may sometimes be seen at mid-day, either east or west of the Sun; and Dr. Dick considers the day-time most favorable for observing her with a telescope.]

250. *How long is Venus alternately Morning and Evening Star?*

For 292 days, or from one conjunction to another.

251. *What did the ancients think of the Morning and Evening Stars?*

They supposed they were two different stars.

252. *What did they call them?*

They called the Morning Star *Phosphor*, and the Evening Star *Hesperus*.

NATURAL APPEARANCE OF VENUS IN DIFFERENT POSITIONS.

[1. On the *left* Venus is seen in the east as *Morning Star*, at various distances from the Sun, and on the *right* as *Evening Star*.
2. We would earnestly recommend to the student to ascertain where Venus is at the time he is learning this lesson, and to watch her for a few weeks, and see if her movements do not answer to the description here given.]

253. *What is the greatest elongation of Mercury?*

It varies from 16 to 29 degrees.

[This proves the orbit of Mercury also to be elliptical.]

254. *Is Mercury often seen?*

He is not.

255. *Why not?*

Because generally so near the Sun as to be hid from our view by his beams.

256. *In what months must Mercury be seen, if at all?*

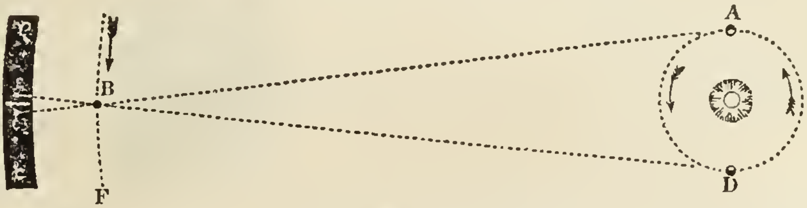
In March and April, August and September.

[By consulting an Almanac, you can ascertain when he is at his greatest elongation, and if it is *eastward*, look out for him low down in the west, just after sunset. If his elongation is *westward*, he must be looked for *in the east*, before sunrise. It will be worth rising early to see him.]

257. *How do you account for the apparent retrograde motion of the Exterior planets?*

It is caused wholly by the change of the Earth's position, in revolving around the Sun.

RETROGRADE MOTION OF THE EXTERIOR PLANETS.



[1. Suppose the Earth at A, and the planet Neptune at B, he would then appear to be at C, among the stars; but as Neptune moves but a little from B toward F, while the Earth is passing from A to D, Neptune will appear to retrograde from C to E. Whatever Neptune may have moved, however, from B toward F, will go to reduce the amount of retrogression.

2. It is obvious from this figure, that the more distant an exterior planet is, and the slower it moves, the less will be its arc of retrogradation, and the longer will it be retrograding. Neptune appears to retrograde 180 days, or nearly half the year.

3. The student will now see the philosophy of the following table, in which may be seen the *amount of arc* and the *time* of retrogradation of the principal planets:

	Arc.	Days.
Mercury	$13\frac{1}{3}$°	23
Venus	16	42
Mars	16	73
Jupiter	10	121
Saturn	6	139
Herschel	4	151
Neptune	1	180]

LESSON XV.

DIURNAL REVOLUTIONS OF THE PLANETS, TIME, ETC.

258. *What is meant by the Diurnal Revolution of a planet?*

Its revolution upon its own axis, causing day and night.

[The regularity with which the Earth revolves upon her axis, is referred to in the following beautiful language of the prophet: "Thus saith the Lord, If ye can break my covenant of the day, and my covenant of the night, and that there should not be day and night in their seasons; then may also my covenant be broken with David," &c. Jeremiah xxxiii. 20.]

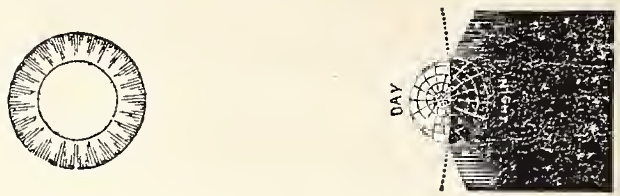
259. *On which side of a planet is it Day?*

On the side toward the Sun.

260. *Where is it Night?*

On the side opposite the Sun.

PHILOSOPHY OF DAY AND NIGHT.



261. *What, then, does the time of a planet's revolution upon its axis constitute?*

Its *day;* including a day and a night.

262. *What is meant by a Solar Day?*

It is the time elapsing from the Sun's crossing a meridian, to his coming to the same meridian again.

263. *How long does this require?*

Twenty-four hours.

264. *What is a Sidereal Day?*

It is the time required for the apparent revolution of a *star* from the meridian around to the same meridian again.

265. *What is the length of a Sidereal Day?*

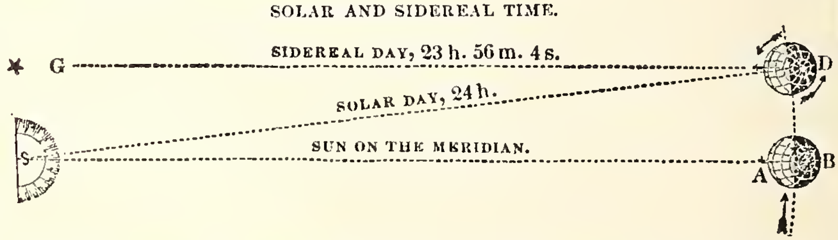
Twenty-three hours, 56 minutes, and 4 seconds.

266. *What, then, is the difference between a Solar and Sidereal Day?*

About *four minutes*, the solar day being the longest.

267. *Will some one of the class explain the cause of this by a diagram upon the blackboard?*

SOLAR AND SIDEREAL TIME.



[1. To the man at A the Sun (S) is exactly on the meridian, or it is twelve o'clock, noon. The Earth passes on from B to D, and at the same time revolves on her axis.

When she reaches D, the man, who has stood on the same meridian, has made a complete revolution, as determined by the star G (which was also on his meridian at twelve o'clock the day before), but the Sun is now *east* of the meridian; and he must wait *four minutes* for the Earth to roll a little further eastward, and bring the Sun again over his north and south line.

2. It is obvious that if the Earth was not revolving around the Sun, her solar and sidereal days would be the same; but as it is, she has to perform a little more than one complete revolution each solar day, to bring the Sun on the meridian.]

268. *What is the annual difference between Solar and Sidereal Time?*

It amounts to one day in every $365\frac{1}{4}$.

269. *Why is this?*

Because it takes 366 actual revolutions of the Earth, as measured by the fixed stars, to produce $365\frac{1}{4}$ natural days.

270. *How does Longitude on the Earth affect our local time?*

Every 15° *east* makes it an hour earlier, and every 15° *west* an hour later.

271. *Why is this?*

Because, if the Sun pass through 360° every 24 hours, he must pass over 15° each hour; as $360° \div 24 = 15°$.

272. *When it is sunrise at New York what time is it 90° east of New York?*

Twelve o'clock.

273. *When it is 12 o'clock at New York what time is it 30° west of that point?*

Ten o'clock.

274. *In what time does each planet revolve upon its axis; or, in other words, what is the length of a day upon each of the planets?*

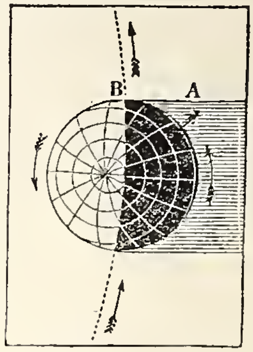
Mercury	24 hours.	The Asteroids	unknown.
Venus	$23\frac{1}{2}$ "	Jupiter	10 hours.
The Earth	24 "	Saturn	$10\frac{1}{4}$ "
Mars	$24\frac{1}{2}$ "	Herschel and Neptune,	unknown.

275. *How was it ascertained that the planets revolve on their respective axes?*

By observing the motion of *spots* upon their surfaces, by the aid of the telescope.

276. *In what direction do the planets rotate* on their respective axes?*

DIURNAL REVOLUTION OF THE PLANETS.



Eastward; or in the same direction that they revolve in their orbits.

[1. In the cut we have an arc of the Earth's orbit, and the Earth revolving on her axis as she revolves around the Sun. The *arrows* show the direction in both cases.

2. By holding the book up south of him, and looking attentively at the cut, the student will understand why the Sun "rises" or first appears in the *east*. It is because the Earth revolves eastward. Thus the observer at A is carried round into the light, and sees the Sun rise when he reaches B.]

277. *Upon what four planets are the days nearly equal?*

Mercury, Venus, the Earth, and Mars.

278. *If Jupiter's day is only ten hours long, and his year equal to about twelve of our years* (11 *years*, 317 *days*), *how many days must* he *have in one of* his years?

About 10,397.

[In this computation we reckon 365 days to a year, and 24 hours for a day. If the student thinks we have too many days for a year, in any part of the Solar System, he will please reckon it for himself, and see if we are correct.]

279. *How many days has Saturn in one of his years?*

About 25,000.

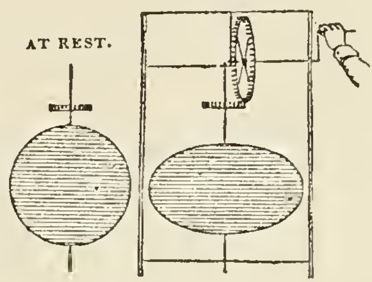
[29 years 175 days = 10,760 days of our time; × 24 = 258,240 hours ÷ $10\frac{1}{2}$ hours, the time of Saturn's revolution, = $24{,}594\frac{3}{10}$, the number of days in his year.]

280. *What effect has the Rotary† motion of the planets upon their form or figure?*

The centrifugal force produced thereby causes them to swell out at their respective equators, and to contract at their poles; thus giving them the form of *oblate spheroids*.

* Ro′-TATE, from *roto*, to revolve or move round a center.

† Ro′-TA-RY, from *rota*, a wheel.



[1. When fluids are left free to yield to the influence of attraction, as mutually existing between their particles, they invariably assume a *spherical form*. Hence water, in falling from the clouds, takes the form of spherical drops; and melted lead, thrown from the top of a shot-tower, takes a spherical form, and cooling in the air on its passage down, remains perfect little globes, called *shot*.

2. Take a ball of India-rubber, pass a rod through its center, and attach it to machinery, so as to give it a rapid rotary motion. When at rest it will be a *sphere;* but when in motion it will contract at its poles, and swell out at its equator, thus becoming an *oblate spheroid;* and its oblateness will be in exact proportion to the rapidity of its revolution.

3. A *solid* sphere would never become oblate by revolution. It might burst, from its powerful centrifugal tendency, as grindstones sometimes do in manufactories of cutlery; but it must be *fluid*, or at least soft and yielding, in order to become oblate by revolution.

4. The oblateness of the planets, then, seems to indicate two things: First, that they were all once in a fluid or plastic state; and, secondly, that they began to revolve while in that state, or before any part of them had become solid, like our continents and islands.

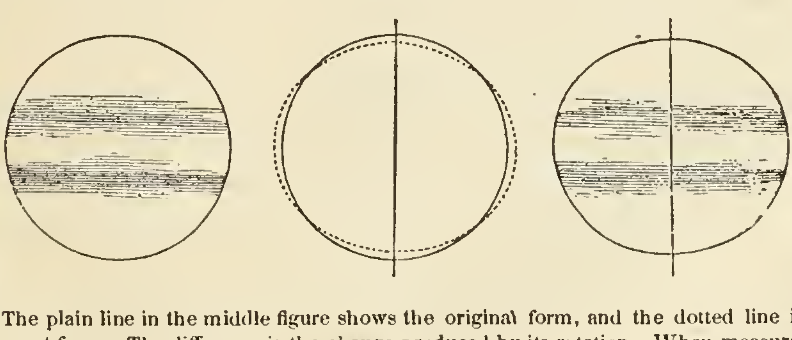
5. So far as the Earth is concerned, we are taught in the Holy Scriptures— the best and most accurate of all books—that the earth and water of our globe were once so mixed, that the whole appeared as a "void" of "waters;" and that they were afterward separated into "earth" and "seas," by the Almighty Creator. (See Genesis i. 2, 9, 10.) Thus we see that true science and the Bible are always in harmony with each other.]

281. *What is the difference, so far as known, between the Equatorial and Polar Diameters of the several planets?*

The Earth 26 miles, Mars 25, Jupiter 6,000, and Saturn 7,500.

[The oblateness of Jupiter and Saturn is as plainly visible through a telescope, as the difference in the following figures is to the eye of the student.

ORIGINAL FORM. CHANGE. PRESENT APPEARANCE.

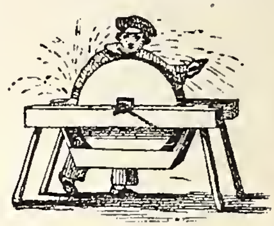


The plain line in the middle figure shows the original form, and the dotted line its present form. The difference is the change produced by its rotation. When measured by the proper instruments, it is found, in the case of Jupiter, to amount to about $\frac{1}{15}$ of his average diameter; and that being 89,000 miles, $\frac{1}{15}$ is but little less than 6,000.]

282. *To what is the great oblateness of Jupiter and Saturn attributable?*

To their rapid revolutions upon their respective axes.

CENTRIFUGAL FORCE.



[The tendency of a rotary motion to engender centrifugal force is illustrated in the adjoining cut, where a boy is seen turning a grindstone so rapidly, as to throw the water from its surface in every direction. In the same manner an increased motion on its axis would make a planet more oblate; and an increased velocity around the Sun would cause them to leave their orbits, and fly off in a tangent, as stated in note after 218.]

283. *If the Earth is oblate, what portions of its surface are nearest to its center?*

Those about the Poles.

284. *Does not the surface ascend then, on the whole, from the Poles to the Equator?*

It does.

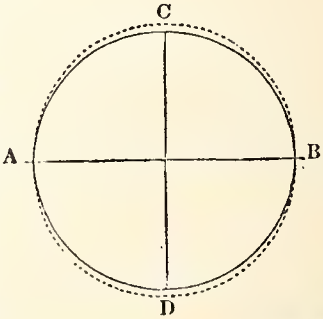
285. *How, then, can rivers run from the Poles toward the Equator, for any great distance, without running up hill?*

They cannot.

[This ascent would be imperceptible in short distances, and where the bed of a river running south from a northern source actually inclined downward; and yet there are circumstances, as we shall see, under which the above answer is strictly correct.]

286. *Can you give an instance of a river running up hill?*

The Mississippi is said to be higher at its mouth than it is some thousands of miles above.



[The plausibility of this opinion may be illustrated by a diagram. Let A B represent the polar, and C D the equatorial diameters. The entire difference between them is 26 miles, or 13 miles on each side. The two circles represent this difference. Now as the Earth's circumference is 25,000 miles, the distance from the poles to the equator (being one-fourth of that distance) must be 6,250 miles; and in that 6,250 miles the ascent is 13 miles, or over two miles to every 1,000 toward the equator. The Mississippi runs from the 50th to the 30th degrees of north latitude inclusive, or 21 degrees; which, at 69½ miles to a degree, would amount to about 1,500 miles. If, then, it runs a distance equivalent to 1,500 miles directly south (in a winding course of about 3,000), theory requires that it should be about three miles higher at its mouth, than it is 1,500 miles directly north. There is some philosophy, therefore, in saying that if a river runs for a great distance from either pole toward the equator, it must run up hill.]

287. *What causes the waters to flow toward the Equator, if they have to ascend in so doing?*

The centrifugal force imparted to them by the Earth's revolution. (See 280 and Illustrations.)

288. *What, then, would be the result if the Earth should cease to revolve on its axis?*

The waters of the equatorial regions would rush toward the Poles, till the Earth again became a perfect sphere.

289. *What would be the effect if the rotation of the Earth upon her axis was greatly increased?*

The waters of the globe would rush toward the equator, and the weight of bodies there would be greatly diminished.

[1. The force of gravity and the centrifugal force are mutual opposing powers, acting against each other. The present rotation of the Earth diminishes the weight of bodies at the equator $\frac{1}{290}$th part, so that if the Earth had no such motion, bodies at her equator would weigh one pound in every 289, *more* than they now do.

2. Should the Earth revolve on her axis every 84 minutes, the centrifugal force would balance that of gravitation, so that bodies at her equator would be without weight; and if the centrifugal force was still further increased by a still more rapid revolution, gravitation would be completely overpowered, and all fluids and loose substances near the equator would fly off from the surface, as the water flies from the grindstone when the boy turns too fast on the opposite page.]

LESSON XVI.

THE ECLIPTIC, ZODIAC, SIGNS, LONGITUDE, ETC.

290. *What is the Ecliptic?*

It is the *plane* of the Earth's orbit, or of the path in which the Sun appears to move in the heavens.

[1. If the student does not fully understand what is meant by "the plane of the Earth's orbit," let him turn back and review Questions 32 to 37, and notes.

2. It is obvious that the *centers* of all circles or ellipses must be *in the planes* of such circles, and as the Earth revolves around the Sun, he, being in the center, must be in the plane of the Earth's orbit; so that the ecliptic and the apparent path of the Sun must coincide.]

291. *Why is the plane of the Earth's orbit called the Ecliptic?*

Because eclipses of the Sun and Moon never take place except when the Moon is in or near this plane.

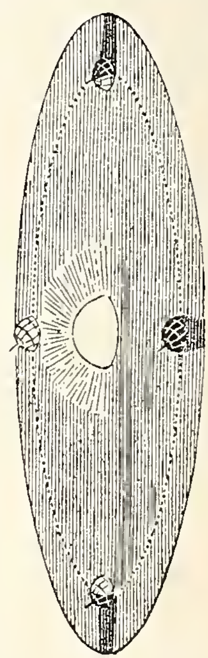
292. *What is the position of the Ecliptic to persons north of the Equator?*

It is *south* of us; runs east and west; cuts the center of the Sun and Earth; and may be imagined as indefinitely extended. (See Note 1 to Question 32.)

[1. The precise position of this plane may always be known by the position of the Sun, which varies its distance north or south at different seasons of the year. The *cause* of this variation will be explained hereafter.

2. In the adjoining cut an attempt is made to represent the ecliptic, or plane of the Earth's orbit. It is an oblique view, which makes the orbit appear elliptical. It shows one-half of the Sun and half the Earth on one side, and half on the other, as above stated. The circle, projecting beyond the orbit, is to represent the plane or ecliptic indefinitely extended.]

PLANE OF THE ECLIPTIC.



293. *What is meant by Above and Below the Ecliptic?*

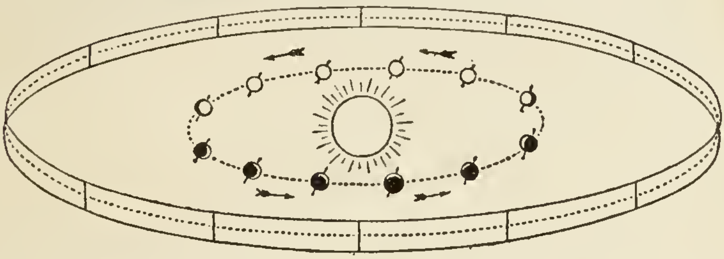
The *Northern* is called the *upper* and the *Southern* the *lower* sides.

[The student must bear in mind, however, that there is no absolute *up* or *down* in the universe. (See 112 and Notes.) He must also guard against the idea that the ecliptic may be *horizontal*. This term has reference only to the Earth, and is descriptive of a plane depending altogether for its own position upon that of the observer, as shown and illustrated at 25. Though the ecliptic is a permanent plane, and cuts the starry heavens around us at the same points from age to age, it has no absolute *up* or *down*, unless it should be the direction to and from the Sun. The distinction of *above* and *below* is merely arbitrary, and grows out of our position north of the equator, which makes the south side of the ecliptic appear down to us.]

294. *What is the Zodiac?*

It is an imaginary belt, 16° wide—namely, 8° on each side of the ecliptic—and extending east and west quite around the heavens.

OBLIQUE HORIZONTAL VIEW OF THE ECLIPTIC AND ZODIAC.



[In this cut the interior dotted circle represents the Earth's orbit; the exterior the *plane* of her orbit extended to the starry heavens. The dark lines each side of the ecliptic are the limits of the zodiac. The Earth is shown in perspective, largest near to us, and growing smaller as her distance is increased. The *arrows* show her direction.]

295. *What is meant by the signs of the Zodiac?*

They are mere divisions of the circle, each of which constitutes one-twelfth part.

[1. The student will consult the definition of a sign and the illustration at Question 75.

2. The twelve signs of the zodiac are divided off in the cut by the perpendicular lines.]

296. *How are the different signs of the Zodiac designated?*

By specific names given to each, and by corresponding symbols or signs.

297. *What are the names of the twelve signs, and their astronomical symbols?*

Aries (or the Ram)	♈	Libra (the Balance).............	♎
Taurus (the Bull).................	♉	Scorpio (the Scorpion)	♏
Gemini (the Twins).............	♊	Sagittarius* (the Archer)......	♐
Cancer (the Crab)...............	♋	Capricornus (the Goat).........	♑
Leo (the Lion)	♌	Aquarius (the Waterman)	♒
Virgo (the Virgin)...............	♍	Pisces† (the Fishes).............	♓

[1. These names being from the Latin, their signification is added in brackets, and should be understood by the pupil. In reciting, however, it is only necessary to give the *first names*—as Aries, Taurus, Gemini, &c.

2. By carefully observing these symbols, the student will detect a resemblance be-

* SAG-IT-TA′-RI-US, from *sagitta*, an arrow. † PI′-SCES.

tween several of them and the objects they represent. For instance, the sign for Aries represents his *horns* ; so also with Taurus, &c.]

298. *Why were these names given to the different signs?*

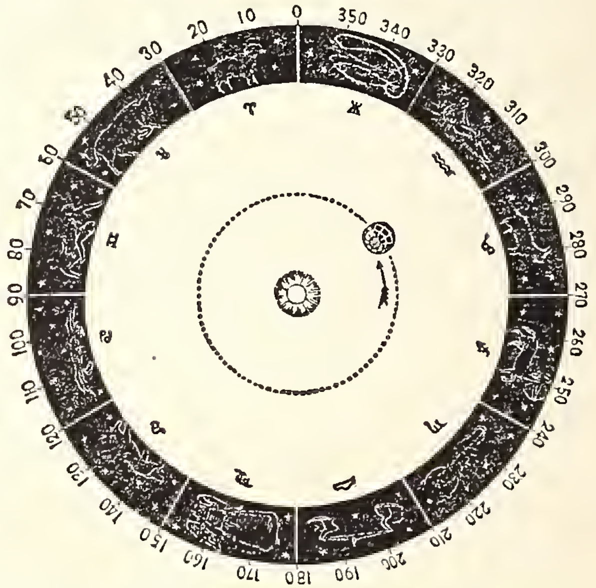
Because the ancients imagined that the clusters of stars in each sign resembled the several objects after which they are named.

[On this account they gave the name *zodiac* to this belt around the heavens. Not, as some have imagined, because it was a *zone*, but from the Greek *zoön*, an animal, because so many animals were represented within its limits.]

299. *In what order are these signs arranged?*

Beginning at *Aries*, they proceed *eastward* around to Pisces.

PERPENDICULAR VIEW OF THE ECLIPTIC.



[1. On pages 64 and 65, we presented *oblique* views of the ecliptic. The above is a *perpendicular* view. The Sun is seen in the center, and the Earth revolving around him; and in the distance is shown the circle of the starry heavens.

2. This circle is divided into twelve equal parts, representing the twelve signs of the zodiac.

3. The *object*, which the stars in each sign were supposed to resemble, is placed in that sign, and the *symbol* immediately opposite and within the sign.]

300. *What influence have these signs upon health, vegetation, or any other terrestrial objects?*

None at all.

ANCIENT ASTROLOGY.

[1. The ancients believed in a pretended science called *Astrology*, and taught that the stars exerted a controlling influence over the destinies of mortals. A fragment of this barbarous superstition may still be met with occasionally in the pages of an almanac, designed to show which part of the human body each sign "governs." The annexed cut is a representation of this heathen absurdity. What an idea for any civilized nation to indulge, that a cluster of stars, millions of miles distant, govern the arms or feet of men!

2. This picture has been published in almanacs, till many people actually think there is some truth in astrology. Hence we sometimes hear them talk of doing things "when the sign is right," or when it is "in the head," or "in the heart." This, also, is founded in error and superstition. The Sun is in certain signs at the same time every year, so that the place of the sign indicates a certain *time*, as much as any given day of the month; and as certain things should be done at certain times, in order to succeed well, it is erroneously concluded that it is because "the sign is right."

3. Impostors often take advantage of this credulity, and profess to "tell fortunes," as they call it, by the aspects of the planets, signs, &c. All these things are based upon erroneous notions respecting the influence of the stars upon our globe and its inhabitants, and should be rejected.]

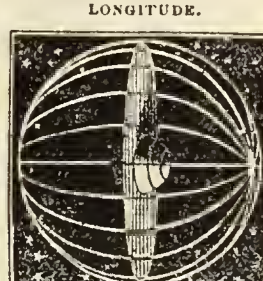
301. *What is Celestial Longitude?*

Distance *east* of a given point in the heavens.

302. *How is it reckoned?*

From the first degree of Aries, around to the same point again, or to 360 degrees.

CELESTIAL MERIDIANS AND LONGITUDE.



[1. Suppose Aries to be on the meridian, as represented page 66. Let the pupil hold his book up to the south of him, and the surface of the page will represent the plane of the ecliptic; and the reckoning of 10, 20, 30, &c., from the top of the cut *eastward*, will answer to the manner in which celestial longitude is reckoned eastward around the heavens.

2. The subject may be still further illustrated by reference to the adjoining cut, in which the celestial concave is represented as a *hollow sphere*, with its *meridians*; and the equinoctial extending to them in every direction. Let the meridian at the top represent the first degree of Aries. Begin at that point, and reckon *toward* you, and 90° will bring you opposite the axis of the Earth, and 90° more, or 180° in all, to the bottom of the figure. You are then half way around the zodiac, and 180° more, apparently from the bottom upward, on the other side of the cut, will bring you to 360°, or the point from which you started.

3. If the observer stood on the upper side of the Earth in the figure, the 90th degree of longitude would be *east*, the 180th under his feet, in the heavens beyond the earth; the 270th *west*, &c.]

303. *Upon what does the apparent Longitude of a planet depend?*

Upon its position in the ecliptic and the point from which it is viewed.

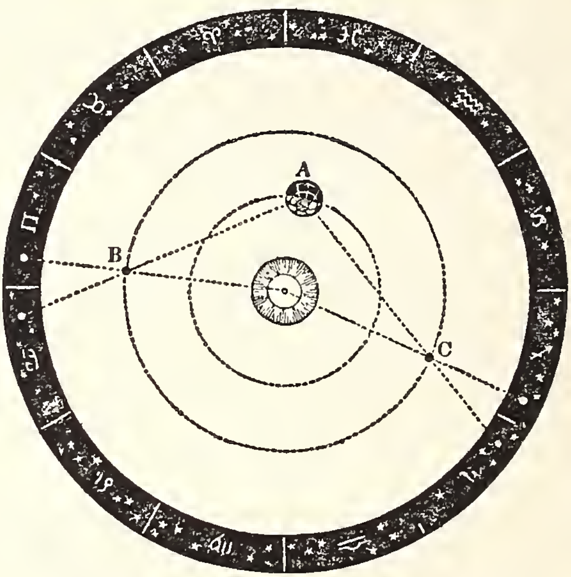
304. *What is Geocentric* Longitude?*

It is the apparent longitude of a planet when viewed from the Earth.

305. *What is Heliocentric† Longitude?*

It is the longitude of an object as seen from the Sun.

GEOCENTRIC AND HELIOCENTRIC LONGITUDE.



[In this cut, the planet B, when viewed from the Earth at A, seems to be in the sign ♋; but when viewed from the Sun, it appears to be in ♊. Again: when at C, her apparent longitude from the Earth is in ♏; when from the Sun, she appears to be in ♐. The reader will not only perceive the difference between *geocentric* and *heliocentric* longitude, but will see why the latter more than the former indicates the true position of the planet. It is an easy thing, however, if one is known, to deduce the other from it.]

* GE-O-CEN′-TRIC, from the Greek *ge*, the Earth, and *kentron*, center: from the Earth, as the center or point of observation.

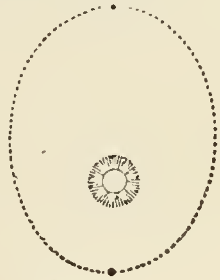
† HE-LI-O-CEN′-TRIC, from the Greek *helios*, the Sun, and *kentron*, center.

LESSON XVII.

FORM AND POSITION OF THE PLANETARY ORBITS, NODES, ETC.

306. *Are the orbits of the planets perfect circles?*

They are not, but are all more or less elliptical.



307. *What is the point nearest the Sun called?*

The *Perihelion.**

308. *What is the most remote point called?*

The *Aphelion*†.

309. *What is meant by the mean distance of a planet?*

It is the average between its greatest and least distances.

[The distances given on page 39 are the mean distances.]

310. *Do the planets revolve with a uniform velocity throughout their respective orbits?*

They do not.

311. *In what part do they move most rapidly?*

When nearest the Sun.

312. *And where most slowly?*

When most distant from the Sun.

313. *Why is this?*

Because from the Aphelion to the Perihelion points the centripetal force *combines with* the centrifugal to accelerate‡ the planet's motion; while from Perihelion to Aphelion points, the centripetal acts *against* the centrifugal force, and *retards*§ it.

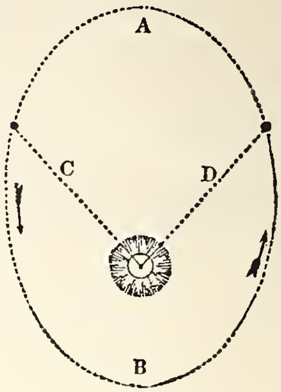
---

* PER-I-HEL'-ION, from *peri*, near, and *helios*, the Sun

† A-PHEL'-ION, *apo*, from, and *helios*, the Sun.

‡ To hasten or cause to move fast.

§ To delay, hinder, or render more slow.



[1. From A to B in the diagram, the centrifugal force, represented by the line C, acts *with* the tendency to revolve, and the planet's motion is *accelerated;* but from B to A, the same force, shown by the line D, acts *against* the tendency to advance, and the planet is *retarded.* Hence it comes to Aphelion with its least velocity; and to Perihelion with its greatest.

2. In the statement of velocities on page 47, the *mean* or *average* velocity is given.]

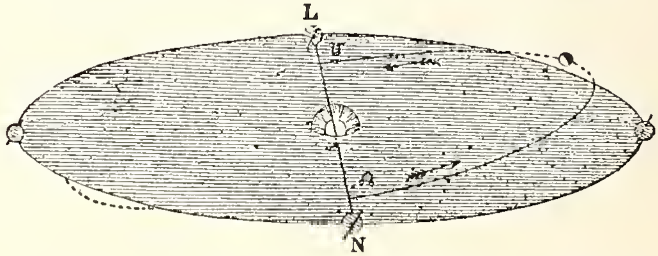
314. *Are the orbits of all the planets in the same plane?*

They are not.

315. *As they all revolve around the Sun as a common center, what is the consequence of their not revolving in the same plane?*

They *cut* or *pass through* the plane of the Earth's orbit.

VENUS PASSING THE PLANE OF THE EARTH'S ORBIT.



316. *What are the points called where a planet passes the ecliptic?*

The *Nodes* of its orbit.

317. *How are the Nodes situated?*

In opposite sides of the ecliptic, or 180° apart. (See preceding cut.)

318. *What is meant by the line of the Nodes?*

It is an imaginary line passing from one node to the other through the Sun's center. (See the line L N in the last cut.)

319. *How are the Nodes distinguished?*

Into *ascending* and *descending.*

320. *Describe each.*

The *ascending* is the one through which the planet passes in coming *above* or *north* of the ecliptic; and the *descending*, that through which it passes in returning *south* of the ecliptic.

321. *What characters are used to denote each?*

The *ascending* is indicated by ☊, and the *descending* by ☋. (See last cut.)

[These characters should be drawn upon a blackboard by the Teacher, or some one of the class.]

322. *Are the Nodes of all the planetary orbits in the same Longitude?*

They are not; but are distributed around the ecliptic.

323. *How do we describe the position of the several planetary orbits?*

By taking the ecliptic as the standard, and recording their deviation from it.

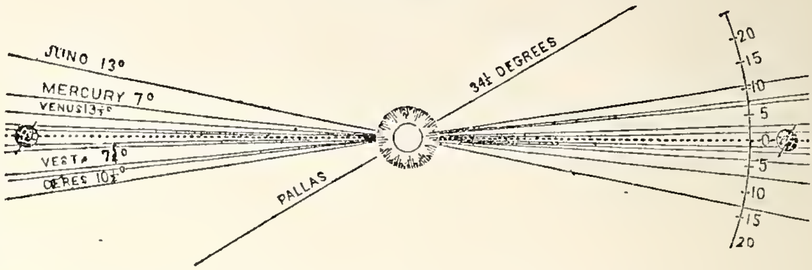
324. *How is this deviation ascertained?*

By marking the greatest distance from the ecliptic at which the planet is ever seen.

325. *What is the deviation of the several orbits from the plane of the ecliptic?*

Mercury	7°	Ceres	11°
Venus	3½	Pallas	34½
Mars	2	Hygeia	4
Flora	6	Parthenope	
Vesta	7	Clio	8½
Iris	5	Jupiter	1¼
Metis	6	Saturn	2½
Hebe	15	Herschel	⅔
Astræa	5	Neptune	1¾
Juno	13		

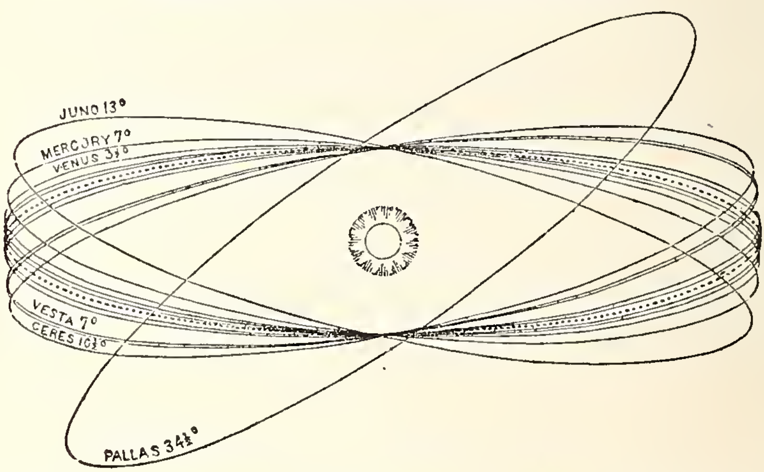
INCLINATION OF THE ORBITS OF THE SEVERAL PLANETS TO THE PLANE OF THE ECLIPTIC.



[1. In this cut, the large line in the center represents the plane of the ecliptic, in which the Earth is seen on the right and left.

2. The other lines crossing the ecliptic at the Sun's center represent the *plane* of the orbits of several of the planets, and their inclination to the ecliptic. There are so many of them, and the inclination of several is so nearly alike, that it is impossible to represent them all in the same figure. The orbits of *Mars*, *Jupiter*, *Saturn*, *Herschel*, and *Neptune* are so near the ecliptic. that it would be difficult to represent their positions at all, except upon a very large scale.

PERSPECTIVE VIEW OF THE PLANETARY ORBITS.



3. A drawing similar to the above may be found in *Long's Astronomy*, vol. i. p. 203: in Smith's Quarto, p. 40; and in several other modern compilations. It may help to form an idea of the inclination of the planetary orbits; but we must guard against the impression it may make that all the planetary *nodes are in the same part of the ecliptic*, as we were obliged to represent in the cut. Instead of this, they are distributed all about the ecliptic. Again: the cut shows the several planets at about the same *distance* from the Sun, contrary to the fact, as stated after Question 175; but, with these exceptions, it is a good illustration.]

LESSON XVIII.

OF TRANSITS.

326. *What is a Transit?*

The passage of a heavenly body over the meridian of any place, or across the disk* of the Sun.

[This term is sometimes used with reference to terrestrial objects, as when we speak of the *transit* or passage of goods through a country. The words *transition*, *transitive*, *transitory*, &c., are derived from the primitive word *transit*.]

327. *When do planets appear to pass over the Sun's face?*

When they pass directly *between* us and him.

328. *Do all the planets make transits across the Sun's disk?*

They do not.†

329. *Why not?*

Because the *exterior* planets can never get between the Earth and the Sun.

[Let the student turn back to 137, and to the cut, page 9.]

330. *What planets, then, make such transits?*

Only *Mercury* and *Venus.*

331. *Do these make a transit at every revolution?*

They do not.

332. *Why not?*

Because the planes of their respective orbits do not lie in the plane of the ecliptic.

[The student will see at once that if the planets all revolved in the same plane, like rolling so many bullets around an apple upon the top of a table, Mercury and Venus would seem to pass over the Sun's face at every revolution. But as one half of each of their orbits is *above* and the other half *below* the ecliptic, they will generally appear to pass either *above* or *below* the Sun. To illustrate:

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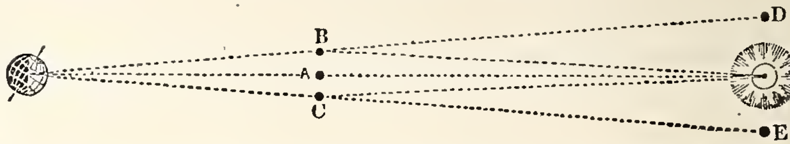
* Disk, the face or visible projection of a heavenly body.

† That is, *to our view;* though they may to the inhabitants of the exterior planets.

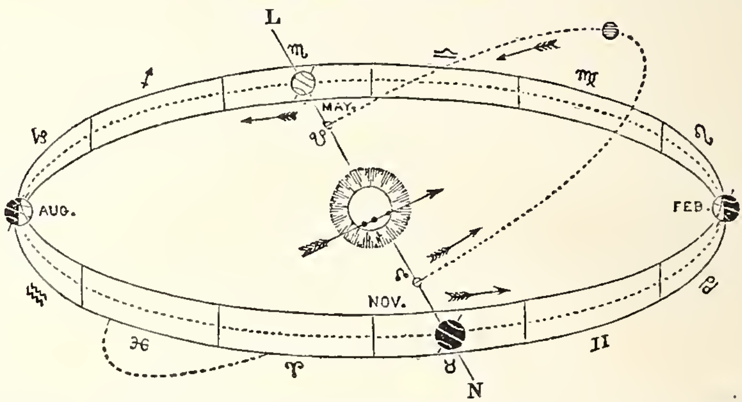


[Let the right line A, joining the Earth and the Sun in the above diagram, represent the plane of the ecliptic. Now when an interior planet is in this plane, as shown at A, it may appear to be upon the Sun's disk; but if it is either above or below the ecliptic, as shown at B and C, it will appear to pass either above or below the Sun, as shown at D and E.]

333. *Under what circumstances, then, do transits occur?*

When the Earth and an interior planet meet on the same side of the ecliptic; the planet being at its node, and the Earth on the line of the nodes.

PHILOSOPHY OF TRANSITS.



[This cut represents the ecliptic and zodiac, with the orbit of an interior planet, his nodes, &c. The line of his nodes is, as shown, in the 16° of ♉ and the 16° of ♏. Now if the Earth is in ♉, on the line L N, as shown in the cut, when Mercury is at his *ascending* node (☊), he will seem to pass *upward* over the Sun's face, like a dark spot, as represented in the figure. On the other hand, if Mercury is at his ☋ when the Earth is in the 16° of ♏, the former will seem to pass *downward* across the disk of the Sun.]

334. *What are the Node Months of a planet?*

The months in which the Earth passes the line of its nodes, and in which all its transits must occur.

[As the Earth's revolution around the Sun constitutes its year, and the two nodes of a planet are in opposite sides of the ecliptic, it follows that the Earth must pass the nodes in opposite months in the year.]

335. *Which are the Node Months of Mercury?*

May and November.

[All the transits of Mercury ever noticed have occurred in one or the other of these months, and for the reason already assigned. The first ever observed took place November 6, 1631; since which time there have been 29 others by the same planet—in all 30—8 in May, and 22 in November.]

336. *When did the last transit of Mercury take place?*

November 9, 1848.

[This transit was observed by Professor Mitchel at the Cincinnati Observatory, and by many others in America and in Europe. The writer had made all necessary preparation for observing the phenomenon at his residence, near Oswego, New York; but, unfortunately, his sky was overhung with *clouds*, which hid the Sun from his view, and disappointed all his hopes.]

337. *When will the next occur?*

November 11, 1861.

[There are to be five besides this during the present century; two in May, and three in November.]

338. *Where does the line of Venus's Nodes lie?*

In Gemini and Sagittarius.

[As the planets all revolve in the same direction, it will be seen, by consulting the last figure, that Venus's ascending node must be in ♊, and her descending node in ♐.]

339. *Which are Venus's Node Months?*

December and June.

340. *Why is this?*

Because the Earth always passes Gemini and Sagittarius during these months.

[This will be obvious by consulting the last cut; for as the line of Venus's nodes is only one sign ahead of that of Mercury, the Earth will reach that point in the ecliptic in one month after she passes the line of Mercury's nodes; so that if his transits occur in May and November, hers should occur in June and December, as is always the case.]

341. *When did the last transit of Venus occur?*

June 3, 1769.

342. *When will the next take place?*

December 8, 1874.

1. Only three transits of Venus have as yet been observed—namely, December 4, 1639; June 5, 1761; and June 3, 1769. It is said that Rittenhouse was so interested in viewing that of 1769, that he actually fainted. In defining the term *transit*, Dr. Webster says: "I witnessed the *transit* of Venus over the sun's disk, June 3, 1769." (See "Unabridged" Dictionary.)

2. The next four will occur December 8, 1874; December 5, 1882; June 7, 2004; and June 5, 2012.]

LESSON XIX.

THE SUN'S APPARENT MOTIONS, THE SEASONS, ETC.

343. *What are the Sun's apparent motions?*

He appears to revolve daily from east to west around the globe.

344. *By what is this apparent motion produced?*

[For an answer let the student consult his *memory;* but if this fails, he may turn back to Question 14.]

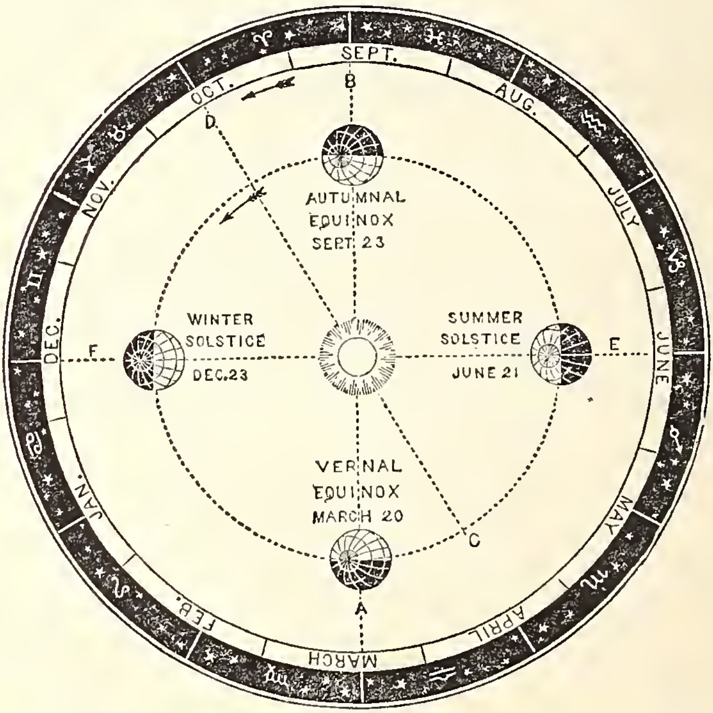
345. *What other apparent motion has the Sun?*

He appears to travel *eastward* through all the signs of the zodiac every $365\frac{1}{4}$ days.

346. *To what is this apparent motion attributable?*

To the revolution of the Earth in her orbit around the Sun.

SUN'S APPARENT MOTION AROUND THE ECLIPTIC.



[Suppose the Earth is at A on the 20th of March; the Sun will appear to be at B in the opposite side of the ecliptic. As the Earth moves on in her orbit from A to C, the Sun will *appear* to move from B to D; and will seem thus to traverse the whole circle of the heavens every 365¼ days, or as often as the Earth revolves around him.]

347. *What is the cause of the different seasons of the year—as Spring, Summer, &c.?*

It is owing to the inclination of the Earth's axis to the ecliptic, and her revolution around the Sun.

348. *How much is the Earth's Axis inclined to the Ecliptic?*

Twenty-three degrees and twenty-eight minutes.

INCLINATION OF THE EARTH'S AXIS TO THE PLANE OF THE ECLIPTIC.

349. *Does the Earth's Axis always incline the same way and to the same amount?*

It does.

[1. This general fact is shown in the cuts, pages 65 and 76, where her axis is seen parallel with itself, or pointing in the same direction, in every part of her orbit.

2. The author is aware that the poles of the Earth have a slow motion around the pole of the ecliptic, requiring 25,000 years for a single revolution; but regarding this and the Precession of the Equinoxes as difficult matters to the juvenile comprehension, and not essential to an explanation of the seasons, &c., has designedly omitted them both.]

350. *What effect has this inclination and permanency of the Earth's Axis in the production of the Seasons?*

As the Earth revolves around the Sun, it brings first one pole toward the Sun and then the other; thus causing a constant variation of light and heat, and producing the seasons.

[1. This may be illustrated by reference to the opposite cut, where the Earth is shown at four different points, with her axis inclined to the left 23° 28'.

2. The student will readily see that if a planet whose axis is thus inclined revolves around the Sun, it must give one hemisphere the most light and heat for half its year, and the other during the remainder. For instance, from A around to B in the cut, the hemisphere toward us would have the most light; while from B around to C again, the opposite one would have the most. This variation in the light and heat received from the Sun at different points on the Earth, during certain months in the year, is what causes the Seasons.

3. Many very intelligent people in other respects, have an idea that the Earth's axis

"wabbles," as they call it, so as to bring first the Northern and then the Southern Hemisphere toward the Sun, and produce the Seasons; but the permanency of the axis effects all this by the simple revolution of the Earth in her orbit.]

351. *Is the Earth's orbit a Circle or an Ellipse?*

It is elliptical, like all the planetary orbits.

352. *Where do her Perihelion and Aphelion points lie?*

Her Perihelion is in *Gemini*, and her Aphelion in *Sagittarius.*

353. *When is the Earth nearest to the Sun, or at Perihelion?*

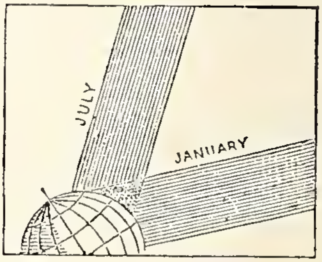
About the first of January.

354. *When is she at her greatest distance?*

Six months afterward, or July 3.

355. *How is it, then, that it is cold in January, when the Sun is nearest; and warm in July, when he is most distant?*

SUMMER AND WINTER RAYS.



It is because the Northern Hemisphere inclines *toward* the Sun in July, and *from* him in January.

[The comparative amount of light received in the Northern Hemisphere in July and January, may be illustrated by the accompanying figure, in which the rays of light at different seasons are represented to the eye. In January they are seen to strike the Northern Hemisphere obliquely; and consequently the same amount of light is spread over a much greater surface. In July the rays fall almost perpendicularly upon us, and are much more intense. Hence the variations of temperature which constitute the Seasons.]

356. *What is the difference of the Earth's distance in July and January?*

About three millions of miles.

357. *Does not this in reality affect the general temperature of the Earth?*

It undoubtedly does; but the variation of 3,000,000 miles is so slight when compared with the whole distance of the Sun, that the change of temperature produced thereby is imperceptible.

[The natural effect of this variation would be, so far as it had any influence, to modify the cold and heat in the Northern Hemisphere, and to augment both in the Southern. For instance, our nearness to the Sun in January would slightly soften our Winter, while, at the same time, it slightly increased the heat of the Summer south of the equator. So, also, our increased distance in July would diminish the heat of our Summer, and at the same time enhance the cold of the corresponding Winter in the Southern Hemisphere.]

358. *What are the Equinoctial Points in the Earth's orbit?*

They are two points, 180° apart, where the Sun shines perpendicularly upon the *equator;* or, in other words, is *in the Equinoctial.*

[1. The Earth is shown at these points in the cut, page 76. See A and B.

2. If the Sun is vertical at the equator, he will, of course, shine to both poles, as represented in the cut, and the days and nights will be equal all over the world. Hence the name *equinoctial*, from the Latin *æquus*, equal, and *nox*, night.]

359. *How are the Equinoctial Points distinguished?*

Into Vernal and Autumnal.

360. *Why this distinction?*

Because the Earth passes one on the 20th of March, when the Sun crosses the equator northward, and Spring begins; and the other on the 23d of September, when the Sun passes south of the equinoctial, and Autumn begins. (See cut, page 76.)

361. *What effect has the inclination of the Earth's Axis and her Annual Revolution upon the apparent motion of the Sun?*

It causes him to appear to change his path in the heavens, coming up north nearly overhead in the Summer, and dropping low down in the south in the Winter.

362. *What is this variation of the Sun north and south of the Equator called?*

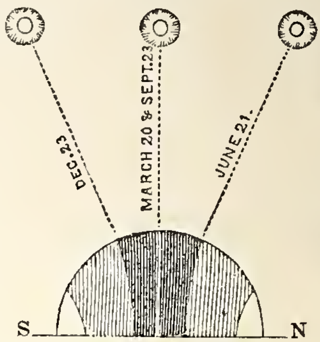
His declination. (See 116.)

363. *How far does the Sun decline north and south of the Equator?*

Only 23° 28′ on each side, or as far as the Tropics. (See 97 and 98, and Notes.)

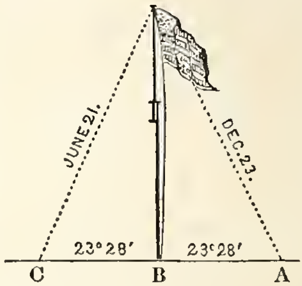
[1. The apparent position of the Sun with respect to the equator, at different seasons of the year, may be illustrated by the annexed cut. On the 21st of June he has his greatest *northern* declination, or *Summer Solstice*, and is vertical on the Tropic of Cancer. From this time he approaches the equator of the heavens till the 20th of September, when he crosses it, and begins to decline *southward*. On the 23d of December he has reached his greatest *southern* declination, or *Winter Solstice*, and begins to return toward the equinoctial, which he passes on the 20th of March, and reaches his Summer Solstice again on the 21st of June. In this manner he continues to decline, first north and then south of the equator, from year to year. If the student does not fully understand the *cause* of the Sun's declination, let him turn back and consider 347, and carefully observe the cut on the same page.

SUN'S DECLINATION.

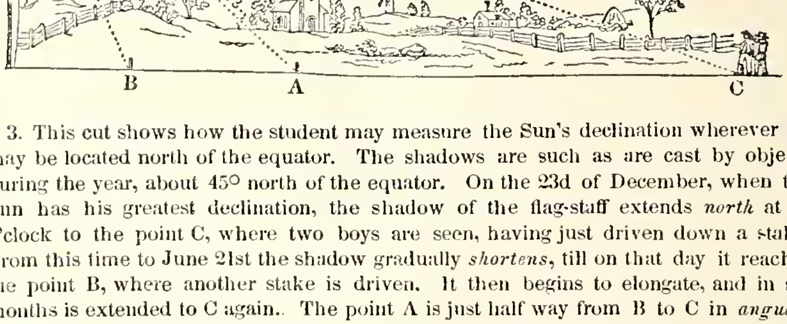


2. The Sun's declination may be easily measured by the shadow of a suitable object upon the Earth's surface. Suppose the flag-staff in the cut to stand perpendicularly, and exactly on the equator. On the 23d of December the shadow would be thrown *northward* to A, or 23° 28′—just as far as the Sun has declined south. At 12 o'clock, on the 20th of March, and the 23d of September, there would be *no shadow* ; and on the 21st of June it would extend *southward* 23° 28′ to C. Thus, at the equator, the shadow falls first north and then south of all perpendicular objects, for six months alternately.

SHADOWS AT THE EQUATOR.



MEASURING THE SUN'S DECLINATION IN NORTHERN LATITUDE.



3. This cut shows how the student may measure the Sun's declination wherever he may be located north of the equator. The shadows are such as are cast by objects during the year, about 45° north of the equator. On the 23d of December, when the Sun has his greatest declination, the shadow of the flag-staff extends *north* at 12 o'clock to the point C, where two boys are seen, having just driven down a stake. From this time to June 21st the shadow gradually *shortens*, till on that day it reaches the point B, where another stake is driven. It then begins to elongate, and in six months is extended to C again. The point A is just half way from B to C in *angular* measurement, though the distances on the plain in the picture are very different.

When the Sun is on the equator, March 21st and September 23d, the shadow will reach only to A; and the angle A B and the top of the staff shows the *northern*, and A C and the top of the staff the *southern* declination. It will be found to be 23° 28′ each way, as marked in the figure.

4. The angle formed by the top and bottom of the pole and the point A will exactly correspond with the latitude of the place where the experiment is made.

5. Let the students try this matter for themselves. Select a level spot, and put up a stake, say ten feet high. Get an exact "noon mark," or north and south line, where the stake is driven, and at 12 o'clock, every fair day, put down a small stake at the end of the shadow. In this manner you will soon be able to measure the Sun's declination for yourselves; to determine the latitude of the place where you live; and to understand how mariners at sea ascertain their latitude by the declination of the Sun.

6. The ancients had pillars erected for the purpose of making observations upon their shadows. Such a pillar is called a *gnomon.*]

364. *What are the Solstitial Points?*

They are those points in the Earth's orbit where the Sun ceases to decline north or south, and begins to return toward the equinoctial.

[See the points E and F in the cut, page 76.]

365. *How are the Solstices distinguished?*

Into *Summer* and *Winter*.

366. *Why are they thus distinguished?*

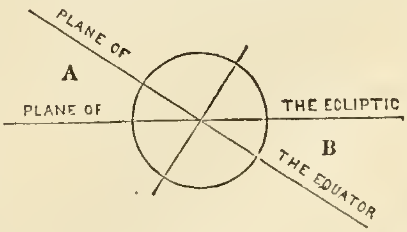
Because the Earth passes one on the 23d of December, or in the Winter; and the other on the 21st of June, or in the Summer.

[By a little attention, the student may observe that the Sun is most directly overhead in the Northern Hemisphere on the 21st of June, and lowest in the south on the 23d of December. From June 21st to December 23d he appears to go southward, while from December 23d to June 21st he comes northward; thus producing the agreeable changes and the unnumbered blessings of the seasons.]

367. *What is meant by the Obliquity of the Ecliptic?*

It is the angle which the equinoctial makes to the ecliptic, in consequence of the inclination of the Earth's axis.

OBLIQUITY OF THE ECLIPTIC.

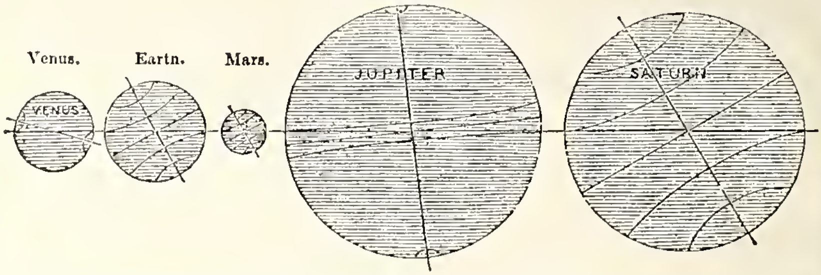


[Here it will be seen that in the same proportion that the axis of the Earth inclines from a perpendicular toward the ecliptic, the *equator* of the Earth must depart from the plane of the ecliptic; and as the axis inclines 23° 28′, the equinoctial departs 23° 28′. This angle, thus formed, shown at A and B, constitutes the obliquity of the ecliptic.]

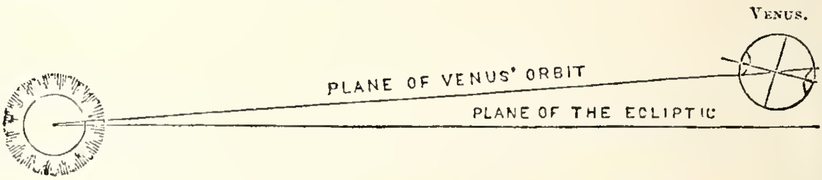
368. *How are the Axes of the other planets inclined to the Planes of their respective Orbits?*

Mercury..................	unknown.	Jupiter	5° 3
Venus	75° 00′	Saturn	26 50
Mars.......................	28 42	Herschel and Neptune	unknown.

INCLINATION OF THE AXES OF THE SEVERAL PLANETS TO THE PLANES OF THEIR ORBITS.



[The student must bear in mind, that the inclination above represented is not to the *ecliptic* (with the exception of the Earth), but *to the planes of their several orbits;* for instance:



The *orbit* of Venus departs from the *ecliptic* 3½°, as stated at 325, while her *axis* is inclined to the plane of her orbit 75°, as shown in the above figures. This distinction should be kept definitely in view by the student.]

LESSON XX.

SEASONS OF THE DIFFERENT PLANETS, TELESCOPIC VIEWS, ETC.

369. *What influence has the inclination of a planet's axis upon its Seasons?*

It determines the extent of its zones; or, in other words, the amount of the Sun's declination north and south of its equator.

[If this is not clear to the mind of the student, let him consult the first of the above diagrams, from which it will be obvious that the less the inclination the narrower the Torrid Zone, and the smaller the Polar Circles.]

370. *What influence has the Periodic Time of a planet upon its Seasons?*

It determines their length.

[As the axes of the several planets are permanent, they can have but four regular seasons in their year, however long it may be.]

371. *What can you say of the Seasons of* VENUS?

Her Tropics are within 15° of her Poles, making her Torrid Zone 150° wide. The Sun passes from one Tropic to the other and back in 225 days, during which time she has her four seasons of $56\frac{1}{4}$ days each.

372. *Describe the Seasons of* MARS.

They are much the same as those of our Earth, except that they are *longer*.

[As the year of Mars consists of 687 days, his four seasons must consist of 172 days each, or nearly twice the length of the seasons of the Earth.]

373. *Has* JUPITER *any change of Seasons?*

Scarcely any. His axis being inclined to his orbit only 5° 3′, the Sun never departs more than 5° 3′ from his equator.

374. *What effect does that have?*

It causes perpetual summer at his equator, perpetual winter at his poles, and gives the intermediate regions an almost unchangeable temperature.

375. *By what are the Seasons of* SATURN *distinguished?*

His zones are much like those of our globe, but each of his seasons is about $7\frac{1}{2}$ years long.

[He has four seasons in his periodic time, the same as the Earth and other planets; and as that is about 30 years, each season must consist of about $7\frac{1}{2}$ years.]

376. *How long are his Poles alternately in the light and shade?*

For about fifteen years.

377. *Have we any knowledge of the Seasons of* HERSCHEL *and* NEPTUNE?

None, except that, being very remote from the Sun, their general temperature must be very low.

378. *Are all the Primary Planets visible to the naked eye?*

They are not.

379. *Which of them can be thus seen?*

Mercury, Venus, Mars, Vesta, Jupiter, and Saturn.

[It is stated upon pretty good authority, that Herschel has been seen, under very favorable circumstances, as a star of the sixth or seventh magnitude; but, as a general thing, he is invisible, except by the aid of the telescope.]

380. *How does* MERCURY *appear to the naked eye?*

As a star, always in the neighborhood of the Sun.

381. *How does he look through a Telescope?*

Like a *globe* or *world*, with numerous *spots* upon its surface.

382. *What are these Spots supposed to be?*

The natural divisions of the planet—as Continents, Islands, Mountains, &c.

[Schroeter, an eminent German astronomer, measured several mountains upon the surface of this planet, one of which he found to be nearly eleven miles in hight.]

383. *What is the general* COLOR *and appearance of* MERCURY?

Through a telescope he has a faint bluish tint, and exhibits a great variety of forms or appearances.

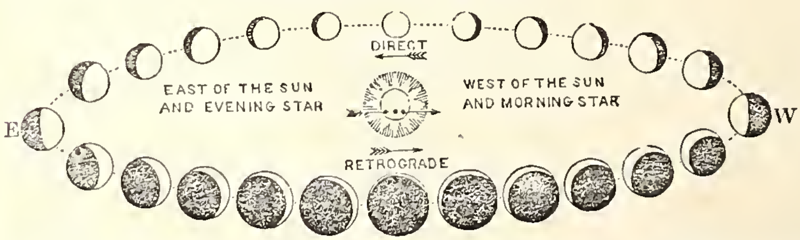
384. *What is the natural appearance of* VENUS?

Her color is of a silvery white; and when at a distance from the Sun, either east or west, she is exceeding bright and beautiful.

385. *How does she appear through a Telescope?*

As she passes around the Sun she exhibits all the varying phases of the Moon.

TELESCOPIC PHASES OF VENUS.



[1. The telescopic appearance of Venus, at different points in her orbit, is represented in the last figure. At E and W she has her greatest eastern and western elongation, and is stationary; while her positions opposite the words "direct" and "retrograde" represent her at her conjunctions. The spots on the face of the Sun represent Venus projected upon his disk, in a transit, the arrow indicating her direction.

2. Before the discovery of the telescope it was asserted, that if the Copernican theory were true, Mercury and Venus would exhibit different phases at different times; and as those phases could not be seen, it was evident that the theory was false. But no sooner had Galileo directed his small telescopes to these objects, than he found them exhibiting the very appearances required by the Copernican theory, its opponents themselves being judges.]

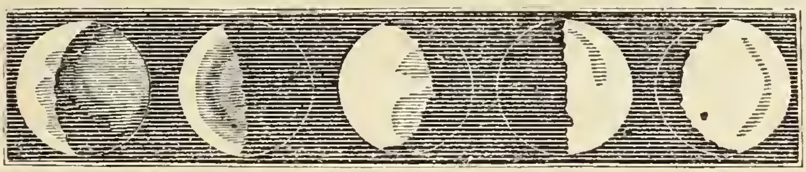
386. *Explain the cause of the different Phases of Mercury and Venus.*

It is because we see more of their enlightened sides at one time than at another.

387. *What else does the Telescope reveal upon Venus?*

A variety of *spots*, probably Islands, Continents, and Seas.

SPOTS SEEN UPON THE DISK OF VENUS.



388. *Has Venus any Mountains?*

She has; some of which are supposed to be over twenty miles in hight.

[Three elevations upon her surface have been estimated at 10¾, 11½, and 19 miles, respectively.]

389. *What can you say of her Atmosphere?*

It is supposed to be *very dense*, and to surround the planet only to the depth of about three miles.

[The atmosphere of our own globe is supposed to extend about forty miles from its surface, or thirteen times as far as that of Venus.]

390. *Why is it thought that the Spots seen upon Mercury and Venus are the great natural divisions of their surfaces?*

Because such divisions would appear like spots, if viewed from a distance, and would vary as the planets revolved, precisely as the spots vary upon Mercury and Venus.

391. *How would the Continents, Islands, and Seas of our Globe appear at the distance of Mercury and Venus?*

As mere *spots* upon its surface, resembling those seen upon those planets.

DISTANT TELESCOPIC VIEWS OF THE EARTH.

1. 2. 3. 4.

[Above we have four different views of our own globe. No. 1 is a view of the Northern Hemisphere; No. 2, of the Southern; No. 3, of the Eastern Continent; No. 4, of the Western. A common terrestrial globe will present a different aspect from every new position from which it is viewed; as the Earth must in her appearance to the inhabitants of other worlds.]

392. *How does* MARS *appear to the naked eye?*

Like a bright star of a reddish color.

[Just east of the "Seven Stars," or *Pleiades*, the student will find another group called the *Hyades*; one of which, called *Aldebaran*, is of a reddish cast, and somewhat resembles the planet Mars. When Mars is in opposition, however, at his nearest point to us, and with his enlightened side toward us, he appears much larger and brighter than Aldebaran. See the position of Mars when in opposition, as illustrated by the cut, page 50.]

393. *How does he appear through a Telescope?*

He has a reddish hue, and exhibits slight phases, and a variety of spots upon his disk.

394. *What is supposed to be the cause of the peculiar Color of Mars?*

It is attributed to his extended and very dense atmosphere.

[When the sunlight passes through vapor or clouds in the morning or evening, the different rays of which it is composed are separated, and the *red rays* only pass to the Earth, giving to the clouds a gorgeous crimson appearance. In a similar manner it is supposed that the atmosphere of Mars may give him his crimson hue.]

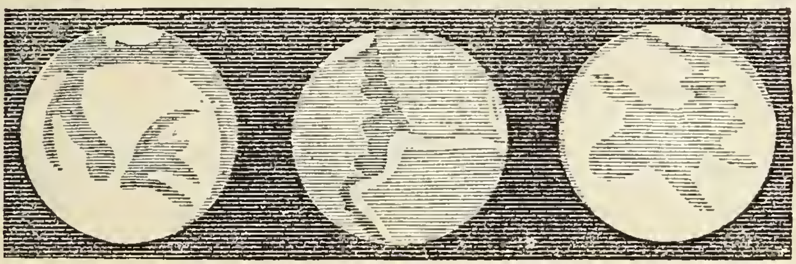
395. *What do astronomers think of the Spots upon his surface?*

"Upon this planet," says Dr. Herschel, "we discern, with perfect distinctness, the outlines of what may be Continents and Seas."

396. *What peculiar changes are seen to take place about his Poles?*

When it is Winter at his north pole, that part of the planet is *white*, as if covered with ice and snow; but as Summer returns to his Northern Hemisphere, the brightness about his north pole disappears.

TELESCOPIC APPEARANCES OF MARS.



[The right-hand figure represents Mars as seen at the Cincinnati Observatory, August 5, 1845. On the 30th of the same month he appeared as represented on the left. The *middle* view is from a drawing by Dr. Dick.]

LESSON XXI.

TELESCOPIC VIEWS OF THE PLANETS CONTINUED.

397. *What peculiarities do the* ASTEROIDS *present under the Telescope?*

A thin haze is seen around Pallas; and they are all of a pale ash-color, except Ceres, whose color is like that of Mars.

398. *Describe the Telescopic appearance of* JUPITER.

His *form* is seen to be *oblate;* his *color* a *light yellow;* and his disk is streaked with several curious *belts*.

399. *How are these Belts situated?*

On both sides of his equator, and parallel to it.

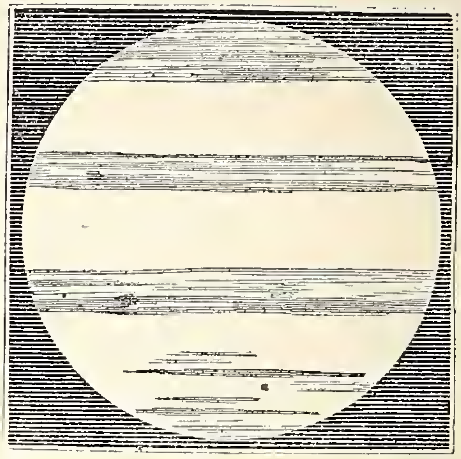
400. *What is their number?*

Only two or three are generally seen, though more are sometimes visible.

[1. Much depends upon the power of the instrument through which he is viewed. An ordinary telescope will show the two main belts, one each side of his equator; but those of greater power exhibit more of these curious appendages. Dr. Herschel once saw his whole disk covered with small belts.

2. The preceding cut represents Jupiter as seen through the great Refracting Telescope at Cincinnati. It is copied from the Sidereal Messenger of February, 1847.]

TELESCOPIC VIEW OF JUPITER.



401. *Do these Belts appear permanent or fluctuating?*

They sometimes continue without change for months, and at other times break up and change their forms in a few hours.

402. *Are they regular or otherwise?*

They are quite *irregular*, both in *form* and *apparent density;* as both bright and dark spots appear in them, and their edges are always broken and uneven.

[The preceding cut affords a good idea of the appearance of these belts, and the spots seen in them.]

403. *What are these Belts supposed to be?*

They are thought to be *openings* in the atmosphere through which the body of the planet is seen.

[The rapid motion of Jupiter upon his axis is supposed to throw the clouds which float in his atmosphere into parallel strata, leaving regular interstices between them, through which the opake body of the planet is seen.]

404. *How are the Spots in these Belts accounted for?*

They are supposed to be caverns, mountains, or something unknown to us, but permanently attached to the body of the planet.

[One of these spots, first observed in 1665, disappeared, and reappeared in the same form for more than forty years; showing conclusively that it was something permanent, and not a mere atmospherical phenomenon.]

405. *What else do we notice in examining* JUPITER *through a Telescope?*

Four small stars are seen near him, and revolving around him.

[1. These are the satellites of Jupiter, of which we shall give a more particular account when we come to speak of the Secondary Planets.

2. The writer once saw all four of these satellites at once, and very distinctly, through a common ship telescope, worth only twelve or fifteen dollars. They were first seen by Galileo with a telescope, the object-glass of which was only one inch in diameter! If the student can get hold of any such instrument whatever, let him try it upon Jupiter, and see if he cannot see from one to four small stars near him, that will occupy different positions at different times.]

406. *How does the body of* SATURN *appear through a Telescope?*

Like an oblate globe, of a lead color, striped with belts, like those of Jnpiter.

[The oblateness of Saturn is really greater than that of Jupiter (Question 281); but as he is more remote than the latter planet, the depression at his poles, &c., is rendered less distinct.]

407. *What remarkable appendage is connected with this Planet?*

He is surrounded by two wonderful *Rings* of a silvery white color.

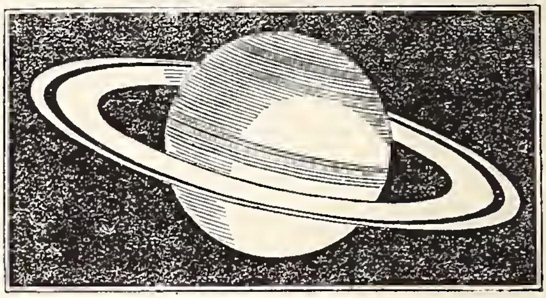
408. *How are they situated with reference to the planet, and to each other?*

They are directly over his equator, the first about 20,000 miles from his surface, and 20,000 miles wide. There is then an opening of 2,000 miles, when we come to the *exterior* ring, which is 10,000 miles wide.

409. *How is it known that these Rings are separate from the body of the planet and from each other?*

From the fact that the fixed stars, in the heavens beyond, have been seen through the openings between them.

TELESCOPIC VIEW OF SATURN.



[1. The writer has often seen the opening between the body of the planet and the interior ring, as distinctly as it appears to the student in the adjoining cut.

2. This is an *oblique* view of the rings, and about the best that can be obtained. It represents the planet as seen at the Cincinnati Observatory, November, 1846.

3. We sometimes see the planet when the *edge* of the rings is turned toward us, but we never get a *perpendicular* view of them. Could the planet be seen from a point over either of his poles, the rings would doubtless appear as represented in this second figure.

4. Under very powerful telescopes, these rings are found to be again subdivided into an indefinite number of concentric circles, one within the other.]

PERPENDICULAR VIEW OF THE RINGS OF SATURN.

410. *What is the thickness of these Rings?*

It is estimated at about 100 miles.

411. *Are they supposed to be solid, like the body of the planet?*

They are; from the fact that they sometimes cast a strong shadow themselves upon the body of the planet; and at other times show the planet's shadow very distinctly upon their own surfaces.

412. *Are they at rest or in motion?*

They revolve eastward around the planet every $10\frac{1}{4}$ hours; or in the time of his rotation upon his axis.

[This revolution resembles that of the rim of a carriage-wheel around the hub, except that there are no *spokes* in the case of Saturn to unite the center to the circumference. This defect, however, is perfectly supplied by the law of gravitation.]

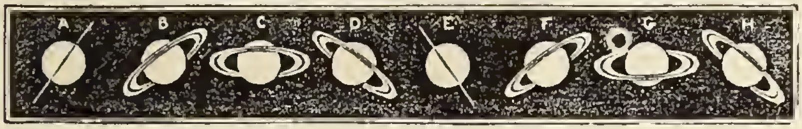
413. *What changes are seen to take place in the appearance of the Rings during the planet's revolution around the Sun?*

The apparent ellipse of the rings seems to contract for about $7\frac{1}{2}$ years, till it almost entirely disappears, when it begins to expand again, and continues to enlarge for $7\frac{1}{2}$ years.

414. *What other change has been noticed?*

For fifteen years the part of the rings *toward* us seems to be *thrown up*, while for the next fifteen it appears to drop *below* the apparent center of the planet

TELESCOPIC PHASES OF THE RINGS OF SATURN.

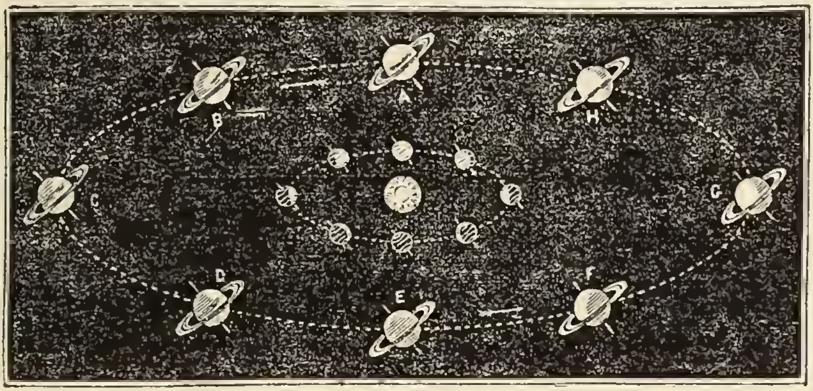


[The *cause* of these varying appearances of Saturn will be easily understood by examining the next cut and the accompanying notes.]

415. *How are these Rings affected as respects Light and Shade?*

The Sun shines, alternately, fifteen years upon one side, and fifteen upon the other.

SATURN AT DIFFERENT POINTS IN HIS ORBIT.



[1. Here observe, first, that the axis of Saturn, like those of all the other planets, remains permanent, or *parallel with itself;* and as the rings are in the plane of his equator, and at right angles with his axis, they also must remain parallel to themselves, whatever position the planet may occupy in its orbit.

2. This being the case, it is obvious that while the planet is passing from A to E, the Sun will shine upon the *under* or *south* side of the rings; and while he passes from E to A again, upon the *upper* or *north* side; and as it requires about 30 years for the planet to traverse these two semicircles, it is plain that the alternate day and night on the rings will be 15 years each.

3. A and E are the *equinoctial* and C and G the *solstitial* points in the orbit of Saturn. At A and E the rings are *edgewise* toward the Sun, and also toward the Earth, provided Saturn is in opposition to the Sun. The rings of Saturn were invisible as rings from the 22d of April, 1848, to the 19th of January, 1849. He came to his equinox September 7, 1848, from which time to February, 1856, his rings will continue to expand. From that time to June, 1863, they will contract, when he will reach

his other equinox at E, and the rings will be invisible. From June, 1863, to September, 1870, they will again expand; and from September, 1870, to March, 1877, they will contract, when he will be at the equinox passed September 7, 1848, or $29\frac{1}{2}$ years before.

4. This cut will illustrate Questions 413 and 414. To an observer on the Earth the rings will seem to expand from A to C, and to contract from C to E. So, also, from E to G and from G to A. Again: from A to E the front of the rings will appear *above* the planet's center, and from E to A *below* it.

5. The writer has often seen the rings of Saturn in different stages of expansion and contraction, and *once* when they were almost directly *edgewise* toward the Earth. At that time (January, 1849,) they appeared as a bright line of light, as represented at A and E, after 414.]

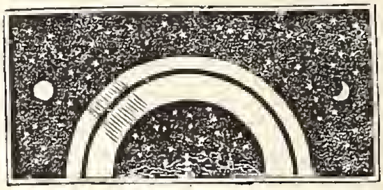
416. *What purposes do these Rings serve, as appendages to Saturn?*

They reflect the sunlight upon his surface, as our Moon does upon the surface of the Earth.

417. *How must they appear to a person upon the body of the planet, either north or south of his Equator?*

Like two gorgeous arches of light, bright as the full Moon, and spanning the whole heavens from east to west.

NIGHT SCENE UPON SATURN.



[In the annexed cut, the beholder is supposed to be situated some 30° north of the equator of Saturn, and looking directly south. The *shadow* of the planet is seen traveling up the arch as the night advances, while a *New Moon* is shown in the west, and a *Full Moon* in the east at the same time.]

418. *How does the* WIDTH *of the two Rings compare with the diameter of the Moon?*

The two rings united are nearly 13 times as wide as the diameter of the Moon.

[The two rings are 30,000 miles wide, which, being divided by 2,160, the diameter of the Moon, gives $12\frac{3}{9}$ as the result.]

419. *How does their* DISTANCE *from Saturn compare with that of the Moon from our globe?*

The nearest ring is only *one-twelfth part* as far from the planet as our Moon is from us.

[1. Divide 240,000 miles, the Moon's distance, by 20,000, the distance of the nearest ring, and we have the above result.

2. At the distance of only 20,000 miles, our Moon would appear some forty times as

large as she does at her present distance. How magnificent and inconceivably grand, then, must these vast rings appear, with a thousand times the Moon's magnitude, and only one-twelfth part of her distance!]

420. *What else does the Telescope reveal in connection with Saturn?*

Eight small stars are seen in his vicinity, which are found to be *Moons* revolving around him.

[These are seen only with good instruments. On one occasion the writer saw five of them at once through the instrument represented in the frontispiece; but the remaining three he has never seen.]

421. *How does* HERSCHEL *appear through a Telescope?*

Like a small ash-colored globe, without rings, belts, or discernible spots.

[Of his six Moons we shall speak in another lesson.]

422. *What can you say of the Telescopic appearance of* NEPTUNE?

In color and general appearance he resembles Herschel.

[So far as is known, Neptune has no rings nor belts, and is attended by only one Moon.]

LESSON XXII.

OF THE SECONDARY PLANETS.

How are the planets of our system divided (133)?

What are the Primary Planets (134)?

Describe the Secondary Planets (135).

Which of these classes have you been considering in the last fourteen lessons?

423. *How many Secondary Planets are there now known to be?*

Twenty.

424. *How are they distributed among the Primaries?*

The Earth has *one*, Jupiter *four*, Saturn *eight*, Herschel *six*, and Neptune *one*.

425. *By what other names are the Secondary Planets known?*

They are often called *Moons* or *Satellites.* (See Note to 135.)

426. *How are they situated with reference to their respective Primaries?*

They are placed at different distances; as the Primaries are placed with respect to the Sun.

427. *What can you say of their motions?*

They revolve around their respective Primaries, from east to west, and at the same time accompanying them around the Sun.

[The Moons of Herschel are said to be an exception to this remark, and to revolve *backward* or *westward*, unlike any other bodies in the Solar System.]

428. *How are their Orbits generally situated?*

In or near the plane of the equators of their respective Primaries.

[Herschel is supposed to be an exception to this rule also: the orbits of his satellites lying almost at right angles with the plane of his orbit. It may be, however, that his axis is nearly parallel with the plane of his orbit, as is the case with Venus; and that his Moons are, after all, in the plane of his equator.]

THE MOON—HER DISTANCE, MAGNITUDE, ETC.

429. *By what name was the Moon known to the ancients?*

The Romans called her *Luna*, and the Greeks *Selene.*

[1. From *Luna* we have our modern terms *lunar* and *lunacy;* the former of which signifies pertaining to the Moon, and the latter a disease anciently supposed to be caused by the Moon.

2. *Selene*, in Mythology, was the daughter of *Helios*, the Sun. Our English word *selenography*—a description of the Moon's surface—is from *Selene*, her ancient name, and *grapho*, to describe.]

430. *How has the Moon generally been regarded by mankind?*

As the most interesting object in the heavens.

[Her beauty has been celebrated in the poetry of every age.]

431. *Why has she attracted so much attention?*

On account of her remarkable changes both of position and appearance.

432. *How is she situated with respect to the Earth?*

She is the nearest of all the heavenly bodies.

433. *What is her average distance?*

About 240,000 miles.

434. *What is her Magnitude?*

Her diameter is 2,160 miles.

435. *How, then, does her bulk compare with that of the Earth?*

She is only $\frac{1}{49}$th part as large.

[The masses of globes are in proportion to the cubes of their diameters. Then 2,160 × 2,160 × 2,160 = 10,077,696,000, the cube of the Moon's diameter; and 7,912 × 7,912 × 7,912 = 495,289,174,428, the cube of the Earth's diameter. Divide the latter by the former, and we have 49 and a fraction over, as the number of times the bulk of the Moon is contained in the Earth.]

436. *How does her diameter compare with that of the Sun?*

It is only about $\frac{1}{400}$th part as great.

[886,000 ÷ 2,160 = 401 $\frac{5}{27}$, the number of times the Moon's *diameter* is contained in that of the Sun.]

437. *What is the apparent diameter of the Moon?*

Thirty-one degrees and seven minutes (31° 7′).

438. *How do the Sun and Moon compare in their apparent magnitudes?*

They appear about of a size.

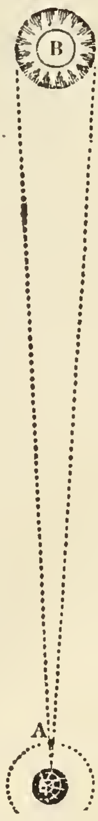
[As the mean angular diameter of the Sun is 32′ 2″, and that of the Moon 31′ 7″, the difference can only be 55″. Both the Sun and Moon vary in their apparent magnitudes, as their distances vary.]

439. *What is their real comparative bulk?*

The Sun is *seventy million times* as large as the Moon.

440. *How is it, then, that they appear so near of a size?*

It is because the Sun is 400 times as far off as the Moon.



[The adjoining cut shows that small as the Moon is, she fills as large an angle at A as the Sun does at B.]

LESSON XXIII.

REVOLUTION OF THE MOON AROUND THE EARTH.

441. *In what direction does the Moon revolve around the Earth?*

From west to east.

442. *Is that her* APPARENT *daily course in the heavens?*

It is not.

443. *What causes her apparent daily revolution westward?*

The revolution of the Earth eastward upon its axis. (See Question 28, and Notes.)

444. *What proof have we that the Moon actually revolves eastward?*

By watching her for a single evening, we can perceive that while she seems to go over us westward, she is actually moving *eastward* among the stars.

445. *Have we any other proof?*

At *New Moon* she is near the Sun in the *west*, and continues to separate from him till *Full Moon*, when she is in the *east*. From that time she approaches the Sun, till she meets and passes him from the west.

446. *What is the* PERIODIC TIME *of the Moon?*

Her *Sidereal Revolution* is performed in $27\frac{1}{3}$ days.

447. *What is meant by her* SIDEREAL REVOLUTION?

It is a revolution from any given point in her orbit around to the same point again. (See 234, and Notes.)

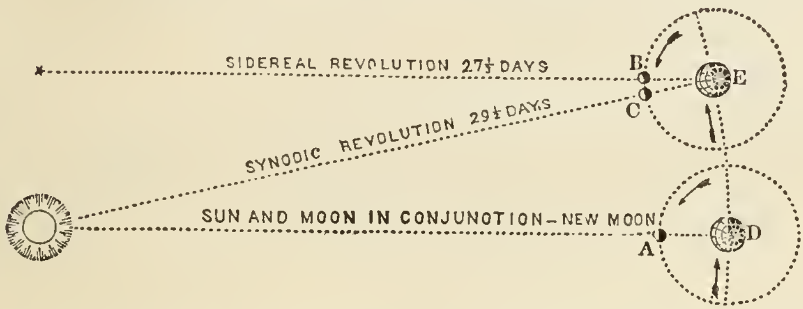
448. *What is a* SYNODIC REVOLUTION *of the Moon?*

It is from one new Moon, or conjunction with the Sun, to another.

449. *Can you state the difference between a Sidereal and a Synodic Revolution of the Moon, and explain it by a diagram?*

The *Sidereal* is one complete revolution; but the motion of the Earth in her orbit renders it necessary for the Moon to perform a little more than a complete revolution each month, in order to come in conjunction with the Sun, and make a *Synodic* revolution.

SIDEREAL AND SYNODIC REVOLUTIONS OF THE MOON.



[1. On the right the Earth is shown in her orbit, revolving around the Sun, and the Moon in her orbit, revolving around the Earth. At A the Sun and Moon are in *conjunction*, or it is *New Moon*. As the Earth advances from D to E, the Moon passes around from A to B, or the exact point in her orbit where she was 27⅓ days before. But she is still west of the Sun, and must pass on from B to C, or 1 day and 20 hours longer, before she can again come in conjunction with him. This 1 day and 20 hours constitutes the difference between a Sidereal and a Synodic revolution.

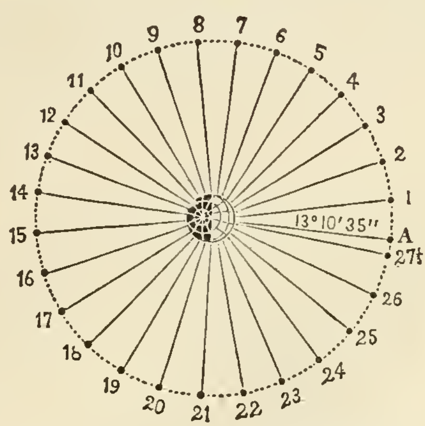
2. The student will perceive that the difference between a Sidereal and Synodic revolution of the Moon, like that between Solar and Sidereal time, is due to the same cause; namely, the revolution of the Earth around the Sun. See Question 267, with the Illustration and Notes.]

450. *What is the daily angular motion of the Moon eastward?*

Thirteen degrees, ten minutes, and thirty-five seconds (13° 10′ 35″).

[This estimate is made for a Solar day of twenty-four hours. In the adjoining cut the daily progress of the Moon may be traced from her conjunction or "change" at A on the right, around to the same point again. This being a *Sidereal* revolution, requires only 27⅓ days.]

DAILY PROGRESS OF THE MOON EASTWARD.



451. *What is the Moon's* Velocity *in her orbit, with respect to the Earth?*

About 2,300 miles per hour.

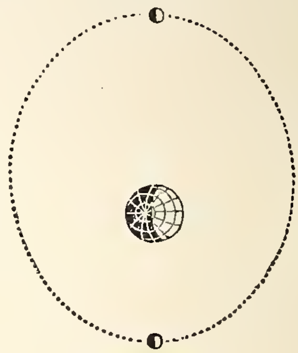
452. *What is the* FORM *of her Orbit?*

With respect to the Earth it is *elliptical*, like those of all the other planets.

453. *When is the Moon said to be in* PERIGEE?

When in that part of her orbit nearest to the Earth.

[The word *Perigee* is from the Greek *peri*, about, and *ge*, the Earth, and signifies *near the Earth.*]



454. *When is the Moon in* APOGEE?

When at her greatest distance from the Earth.

[*Apogee* is from *apo*, from, and *ge*, the Earth.]

455. *What are the* APSIDES *of the Moon's orbit?*

They are the same as the Perigee and Apogee.

[The singular of *ap'-si-des* is *ap-sis.*]

456. *What is the* LINE *of the Apsides?*

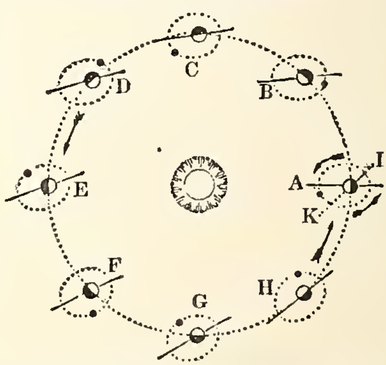
It is a right line from one apsis to the other.

[This is simply the *Major Axis* of the elliptical orbit of the Moon. See Question 87, and cut.]

457. *Is the Line of the Apsides of the Moon's orbit* FIXED *in the Ecliptic, or does it change its direction?*

It revolves from west to east around the ecliptic in about nine years.

MOTION OF THE APSIDES.



[In the adjoining cut an attempt is made to represent this motion. At A the line of the apsides points directly to the right and left, but at B, C, and D it is seen changing its direction, till at E the change is very perceptible when compared with A. But the same ratio of change continues; and at the end of a year, when the Earth reaches A again, the line of the apsides is found to have revolved eastward to the dotted line I K; or about 40°. In nine years the aphelion point near A will have made a complete revolution, and returned to its original position.]

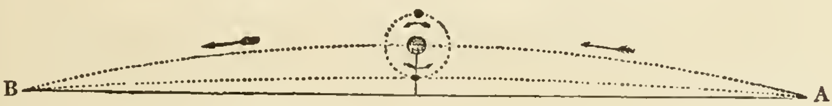
458. *What is the true form of the Moon's path?*

It is an irregular curve, always concave toward the Sun, and crossing the Earth's orbit every 13 degrees nearly.

[1. If the Earth stood still in her orbit, the Moon would describe just such a path in the ecliptic as she describes with respect to the Earth. See 449, and cut.

2. If the Earth moved but slowly on her way, the Moon would actually retrograde on the ecliptic at the time of her change, and would cross her own path at every revolution, as shown in the adjoining figure. But as the Earth advances some 46 millions of miles, or near 100 times the diameter of the Moon's orbit, during a single lunation, it is evident that the Moon's orbit never can return into itself, or retrograde, as here represented.

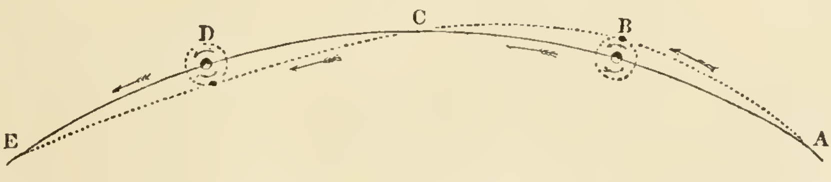
THE MOON'S ORBIT ALWAYS CONCAVE TOWARD THE SUN.



3. That the lunar orbit is always concave toward the Sun, may be demonstrated by the above diagram. Let the upper curve line A B represent an arc of the Earth's orbit, equal to that passed through by the Earth during half a lunation. Now the radius and arc being known, it is found that the chord A B must pass more than 400,000 miles within the Earth. But as the Moon departs only 240,000 from the Earth, as shown in the figure, it follows that she must describe the curve denoted by the middle line, which is concave toward the Sun.

4. This subject may be still further illustrated by the following cut, representing

THE MOON'S PATH DURING A COMPLETE LUNATION.



Here the plain line represents the Earth's orbit, and the dotted one that of the Moon. At A the Moon crosses the Earth's track 240,000 miles *behind* her. She gains on the Earth, till in seven days she passes her at B as a *Full Moon.* Continuing to gain on the Earth, she crosses her orbit at C, 240,000 miles *ahead* of her, being then at her *Third Quarter.* From this point the Earth gains upon the Moon, till seven days afterward she overtakes her at D as a *New Moon.* From D to E the Earth continues to gain, till at E the Moon crosses 240,000 *behind* the Earth, as she had done four weeks before at A. Thus the Moon winds her way along, first within and then without the Earth, always gaining upon us when outside of our orbit, and falling behind us when within it.

5. The small circles in the cut represent the Moon's orbit with respect to the Earth, which is as regular *to us* as if the Earth had no revolution around the Sun.]

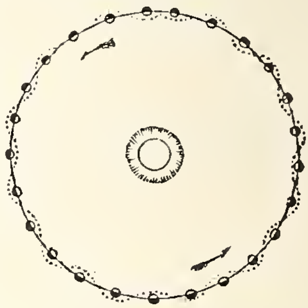
459. *Does the Moon ever actually retrograde upon the Ecliptic?*

She does not.

460. *What is her absolute velocity in space, in accompanying the Earth around the Sun?*

It is never less than 65,700 miles per hour.

MOON'S PATH.



[1. The Moon's orbitual velocity, with respect to the Earth, is about 2,300 miles per hour (451). When outside the Earth, as at B, in the last figure, she *gains* 2,300 miles per hour, which, added to the Earth's velocity (215), would give 70,300 miles as the hourly velocity of the Moon. When *within* the Earth's orbit, as at D, she *loses* 2,300 miles per hour, which, subtracted from 68,000 miles, the Earth's hourly velocity, would leave 65,700 miles, as the slowest motion of the Moon in space, even when she is falling behind the Earth.

2. Could we look down perpendicularly upon the ecliptic, and see the paths of the Earth and Moon, we should see the latter pursuing her serpentine course, first within and then outside our globe, somewhat as represented by the dotted line in the annexed figure. Her path, however, would be concave toward the Sun, as shown in the middle cut, on page 99, and not convex, as we were obliged to represent it here in so small a diagram.]

461. *How is the Moon's orbit situated with respect to the* Ecliptic?

It departs only about $5\frac{1}{8}°$ from that plane ($5° \ 8' \ 48''$).

INCLINATION OF THE MOON'S ORBIT TO THE PLANE OF THE ECLIPTIC.

[Let the line A B represent the plane of the Earth's orbit, and the line joining the Moon at C and D, would represent the inclination of the Moon's orbit to that of the Earth. At C the Moon would be *within* the Earth's orbit, and at D exterior to it; and it would be *Full Moon* at D, and *New Moon* at C.]

462. *Does the Line of the Moon's nodes remain stationary on the Ecliptic?*

It does not; but *retrogrades* or revolves *westward* around the ecliptic every 19 years.

[The amount of this motion is 10° 35′ per annum, which would require 18 years and 219 days for a complete revolution.]

LESSON XXIV.

THE MOON'S CHANGES.

463. *Is the Moon self-luminous, or opake?*

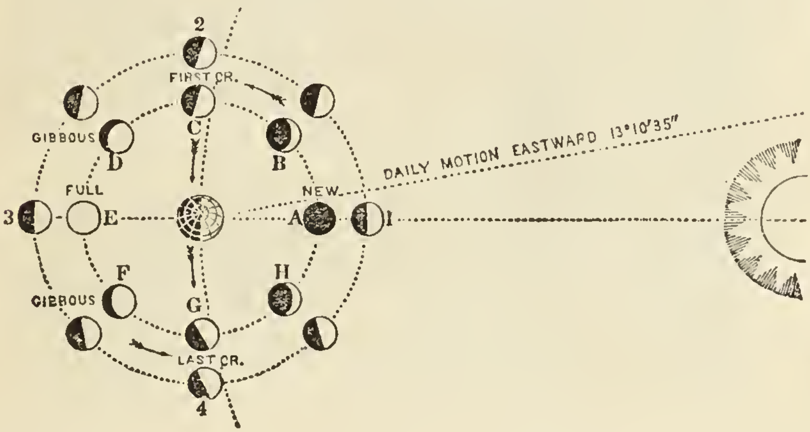
She is opake, like all the rest of the planets, and shines only by reflection.

[This is obvious from the fact that only so much of the Moon is bright as is enlightened by the Sun.]

464. *What is the cause of the various* Phases *of the Moon, as New Moon, Full Moon, &c.?*

It is caused by her revolution around the Earth, which enables us to see more of her enlightened side at one time than at another.

CAUSE OF THE MOON'S PHASES.



[1. The above cut represents the Moon revolving eastward around the Earth. In the outside circle she is represented as she would appear, if viewed from a direction at right angles with the plane of her orbit. The side toward the Sun is enlightened in every case, and she appears like a half Moon at every point.

2. The interior suite represents her as she appears when viewed from the Earth. At A it is New Moon, and if seen at all so near the Sun, she would appear like a dark globe. At B she would appear like a crescent, concave toward the east. At C more of her enlightened side is visible, at D still more, and at E the enlightened hemisphere is fully in view. We then call her a *Full Moon*. From E around to A again the dark portion becomes more and more visible, as the luminous part goes out of view, till she comes to her change at A.

3. If the student will turn his book bottom upward, and hold it south of him, he will see *why* the crescent of the Old Moon at H is concave on the west, instead of the east,

like the New Moon; and why she is seen before sunrise instead of just after sunset. But these points will be called up and more fully illustrated hereafter.]

465. *What is meant by the* CHANGE *of the Moon?*

It is when she is in conjunction with the Sun, and *changes* from what is called an *Old Moon* to a *New Moon.*

[If the student will be on the look-out, he can easily find the Moon *west* of the Sun *in the day-time;* and by observing her carefully, will see that she is rapidly approaching him. In a short time she will be lost in his beams, and soon after will appear *east* of the Sun, just after sundown, as a *New Moon.* This *change*, as it is called, takes place when she passes the Sun eastward.]

466. *What is meant by the* NEW MOON?

It is when she appears in the west like a slender crescent, and during the first seven days after her change.

[1. It is New Moon from A to C in the preceding cut.

NEW MOON IN THE WEST JUST AFTER SUNDOWN.

2. Here is a picture of what you have often seen—the New Moon in the west just after sundown. The Sun is scarcely out of sight, and the Moon is very close to him. She also will set very soon, and be out of sight. A gentleman is pointing her out to two boys and a little girl. They are probably some of his students going to the school-house near by, to a "spelling-school," or to hear a *Lecture on Astronomy.*]

467. *What are the* CUSPS *of the Moon?*

The extremities of the crescent.

468. *What are the Moon's* SYZYGES?

Two points in her orbit 180° apart, where she is New and Full Moon. (See A and E in the cut, page 101.)

469. *What are her* QUADRATURES?

Four points in her orbit, 90° apart. (See positions 1, 2, 3, and 4, page 101.)

470. *What are her* OCTANTS?

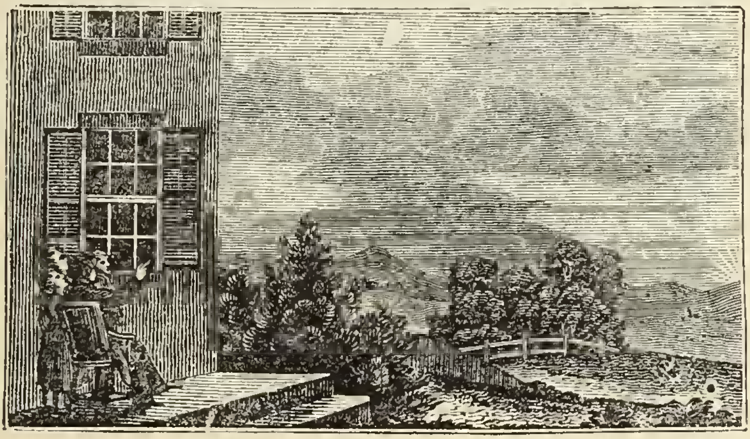
Eight points, 45° apart. (See A, B, C, D, page 101.)

471. *What is the* FIRST QUARTER?

It is when the Moon has performed one-quarter of her journey eastward around the Earth, and appears just one-half enlightened.

[1. At this time the Moon is south of us as the Sun goes down, or 90° from him, and we see one-half of her enlightened side.

THE MOON AT HER FIRST QUARTER.



Here is the same gentleman we saw on the opposite page, now showing his pupils a *Half Moon*, or the Moon at her *First Quarter*. A week ago she was close to the Sun as he went down in the west, and was only a slender crescent; but now she is 90° east of the Sun, so that she is directly south, when he goes down in the west. When the Moon appears as here represented, she is at the point No. 2 in her orbit, as shown in the cut, page 101.]

472. *What is meant by the* FULL MOON?

It is when the Moon appears *round*, and reflects the greatest amount of light upon the Earth.

473. *How is the Moon, then, situated with respect to the Sun?*

They are *in opposition*, or 180° apart.

474. *How is the Full Moon situated with respect to the Earth's orbit?*

She is *outside of it.*

475. *How with respect to the Sun?*

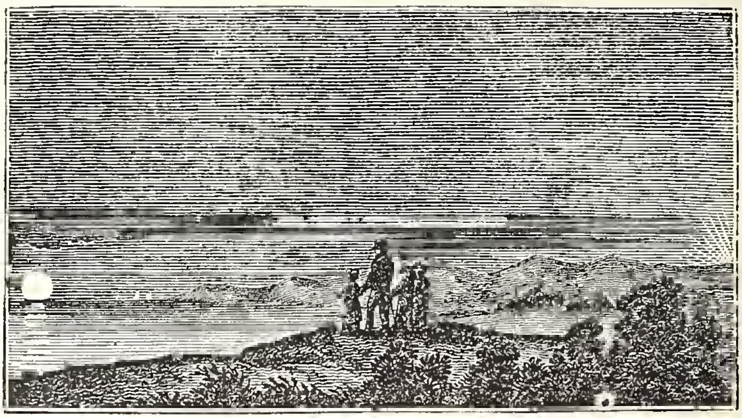
She is at her greatest distance from him.

[The student will understand that the Moon, by revolving around the Earth almost in the plane of the ecliptic, must vary in her distance from the Sun, not only as the Earth varies (346), but to the amount of the diameter of her own orbit, or 480,000 miles, from New to Full Moon. See Illustration, page 101, where the Full Moon is shown at No. 3.]

476. *How does the Full Moon rise with respect to the Sun?*

She rises in the east just as the Sun goes down in the west.

THE FULL MOON RISING AS THE SUN SETS.



[In this picture we see the ***Full Moon*** rising in the east, as the Sun goes out of sight behind the hills in the west. What a splendid Moon! She appears to rise out of the ocean, and to throw her silvery light upon the waves, and upon the sails of the ships far off at sea. The same kind teacher is out again with his students, to enjoy with them a walk by moonlight, and to explain to them still further the cause of the Moon's changes.]

477. *When is the Moon at her* THIRD QUARTER?

When she has passed three-quarters of her journey, from New Moon around the Earth. (See cut, page 101.)

478. *Is she east or west of the Sun at this time?*

West of the Sun, and going toward him.

479. *What is her distance?*

Ninety degrees west.

[At this time she will rise six hours before the Sun; will be south at sunrise; and will set at twelve o'clock.]

480. *How does the Moon appear when at her Third Quarter?*

Just as she does at her First Quarter, except that her eastern side is enlightened instead of the western.

[At A, in the figure, we have a view of the Moon at her *First Quarter*, when she is south as the Sun *sets*, and her western limb is enlightened. At B we see her as she appears when at her *Third Quarter*, when she is on the meridian as the Sun *rises*, and her *eastern* limb is enlightened.]

FIRST AND THIRD QUARTERS.

481. *What is meant by the* OLD MOON?

She is called an Old Moon from the Full to the New, and especially from the Third Quarter to the change.

482. *How does the Old Moon appear?*

Like a slender crescent, much like the New Moon.

483. *Wherein do they differ?*

The cusps of the New Moon point east, and those of the Old Moon west.

484. *When and where can we best see the Old Moon?*

In the east, just before sunrise.

THE OLD MOON BEFORE SUNRISE.

[1. Here the *Old Moon* is seen in the east just before sunrise. It looks just like the *New Moon* shown on page 102, except that the crescent is inverted, the concave side being west instead of east. The teacher is pointing to the Moon, and explaining the difference between her present appearance and that of the New Moon, and the *cause* of that difference. His pupils have become so interested in the subject as to be up and dressed *before sunrise*, to see the Old Moon.

2. The Moon is at this time very near her *change*. At noon she may be seen just

west of the Sun, and in a few days will pass him *eastward*, when she will be a *New Moon* again, seen in the west as the Sun goes down, as represented on page 102. Thus she continues to pass through her changes every $29\frac{1}{2}$ days from age to age.

3. We earnestly recommend to both teacher and student to observe the present place and appearance of the Moon, and watch her through one lunation at least. A little time spent in this way will do more to fix correct ideas in the mind than months of abstract study.]

485. *When is the Moon* GIBBOUS?

When between a Half and a Full Moon. (See "Gibbous," cut, page 101.)

486. *What is meant by the Moon's* WAXING *and* WANING?

She waxes larger from the change to the full; and *wanes*, or grows smaller, from the full to the change again.

LESSON XXV.

DAY AND NIGHT, SEASONS, AND TELESCOPIC APPEARANCE OF THE MOON.

487. *What is the line called which separates the dark from the enlightened portion of the Moon's disk?*

The *Terminator.*

[As just one-half of the Moon is always enlightened by the Sun, whether it appears so to us or not, it follows that the Terminator must extend quite around the Moon, dividing the enlightened from the unenlightened hemisphere. This circle is called the *Circle of Illumination.* At New and Full Moon this circle is *sidewise* to us, but at the First and Third Quarters it is *edgewise.* The portion of the Terminator visible from the Earth traverses the Moon's disk twice during every lunation.]

488. *Has the Moon a Diurnal Revolution?*

She has.

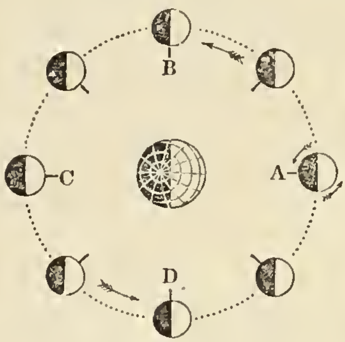
489. *In what time does she revolve on her Axis?*

In $29\frac{1}{2}$ days, or once during every revolution around the Earth.

490. *How is this known?*

From the fact that the same side of the Moon is always toward the Earth.

MOON'S REVOLUTION.



[1. By watching the Moon carefully with the naked eye, it will be seen that the same spots occupy nearly the same places upon her disk from month to month; which shows that the same side is always toward us.

2. Suppose a monument erected upon the Moon's surface, so as to point toward the Earth at *New Moon*, as represented at A. From the Earth it would appear in the Moon's center. Now if the Moon so revolved upon her axis, in the direction of the arrows, as to keep the pillar pointing directly toward the Earth, as shown at A, B, C, and D, and the intermediate points, she must make just one revolution on her axis during her periodic revolution. At A the pillar points *from* the *Sun*, and at C *toward* him; showing that, in going half way round the Earth, she has performed half a revolution upon her axis.]

491. *What is meant by the Moon's* LIBRATIONS?

A slight apparent rolling motion, first one way and then the other.

492. *How are her Librations distinguished?*

As librations in *Latitude*, and librations in *Longitude.*

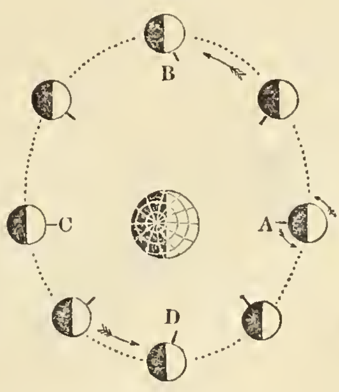
493. *What are her Librations in* LONGITUDE?

A motion by which more of her *eastern* and *western* borders alternately appear and disappear.

494. *What is the* CAUSE *of this Libration?*

It is because her *angular motion* in her elliptical orbit is not uniform, like her motion around her axis.

MOON'S LIBRATIONS.



[1. From A around to C the angular motion is *slower* than the average, and the diurnal motion gains upon it, so that the pillar points *west* of the Earth, and we see more of the *eastern* limb of the Moon.

2. From C to A, again, the Moon advances *faster* than a mean rate, and *gains* upon the diurnal revolution; so that the pillar points *east* of the Earth, and we see more of the Moon's *western* limb. Thus she seems to librate or roll, first one way and then the other, during every periodic revolution.

3. At B we see most of her eastern limb, and at D most of her western.]

495. *What is her Libration in* LATITUDE?

A slight rolling motion, by which the parts about her *poles* alternately appear and disappear.

496. *What is the* CAUSE *of this?*

The inclination of her axis to the plane of her orbit, and her revolution around the Earth.

497. *What is the inclination of her* AXIS *to her* ORBIT?

About a degree and a half (1° 30′ 10″.8).

[If the inclination of the Earth's axis brings first one pole and then the other toward the *Sun*, and produces the Seasons (347), so the inclination of the Moon's axis would bring first one pole and then the other in view from the Earth. But as her inclination is only $1\frac{1}{2}$°, the libration in latitude is very slight.]

498. *What is the Length of a* NATURAL DAY *upon the Moon?*

Twenty-nine and a half of our days.

[A complete revolution upon her axis gives her a *Natural Day*; and if that requires $29\frac{1}{2}$ of our days, her day must be equal to $29\frac{1}{2}$ of ours.]

499. *What is the Length of her* YEAR?

Only $29\frac{1}{2}$ days.

[By the *year* of a planet, we mean the time required for a complete revolution in its orbit, during which it must pass through all its *seasons*. Hence we speak of the year of *Herschel* as being equal to 84 of our years; and that of *Neptune* as equal to 164. (See Question 212.) By applying this rule to the Moon, and measuring her year by her periodic revolution, we find it compressed within the narrow limits of $29\frac{1}{2}$ days.]

500. *What curious fact does this establish?*

That she has only one day in her year; or, in other words, that her days and her years are precisely of a length.

501. *Can the Earth be seen from all parts of the Moon?*

She can only be seen from the one side, which is always turned toward us.

502. *How would the* EARTH *appear from the Moon?*

Like a bright stationary planet, thirteen times larger than the Moon, and exhibiting all her varying phases.

[Turn back and consult the figure, page 101. To the lunarian at A it would be night, and the Earth would appear like a magnificent *Full Moon*. At B she would be at her Third Quarter, and at C like the Moon at her changes, &c. But whatever might be the Earth's phase or appearance, she would always appear *stationary*, or occupying the same position in the heavens. From the apparent center of the Moon the Earth would appear directly overhead, while 90° from that point she would always appear in the horizon.]

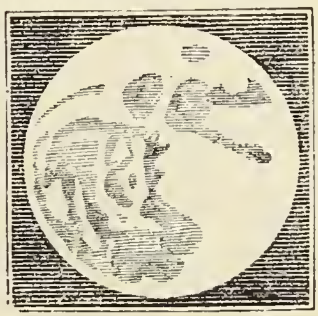
503. *How does the surface of the Moon appear to the naked eye?*

It exhibits a variety of dark lines and spots.

504. *What do they resemble?*

There is a dark figure on her western limb, resembling that of *a man*, with his head to the north, and his body inclined to the east. Just east of him, and opposite his shoulders, is an irregular object resembling a huge *bundle* or *pack*.

NATURAL APPEARANCE OF THE FULL MOON.



[1. Both these objects are represented in the adjoining cut, which was drawn from nature by the author on the evening of December 18, 1850. It represents the Moon as she appears when about two hours high, and is the best of six different sketches taken during the same evening. Let the student compare it with *the next Full Moon*, and see if our drawing is correct.

2. The Ojibway Indians have a legend by which they explain this singular appearance of the Moon. Instead of a "man," they say this figure is a beautiful Ojibway *maiden*, who was translated to the Moon "many snows ago," for having set her affections upon that object, and refusing to marry any of the "young braves" of the Ojibway nation. How the "beautiful maiden" came to look so coarse and masculine, and what the rest of the figure means, the tradition does not inform us.

3. In answer to inquiries sometimes made by children as to this "man," they have been told that it is a man with a bundle of wood upon his back, who was sent to the Moon for his wickedness, in gathering sticks on the Sabbath. This story is less innocent than the Ojibway tale, as it trifles with the subject of disobedience to God, and with the sanctity of the holy Sabbath.]

505. *What are these objects supposed to be?*

The outlines of her great natural divisions, as Mountains, Valleys, and Continents.

[Almost every body has noticed these rude outlines upon the face of the Moon, and many, doubtless, have wondered what they were; but how few have supposed, as they were gazing upon her mottled disk, that they were enjoying a distant view of a *world*; and that these dim outlines were a *natural map* of its nearest hemisphere! Having seen "the Man in the Moon," they have supposed it useless to pursue the subject any further, and here their investigations have ended.]

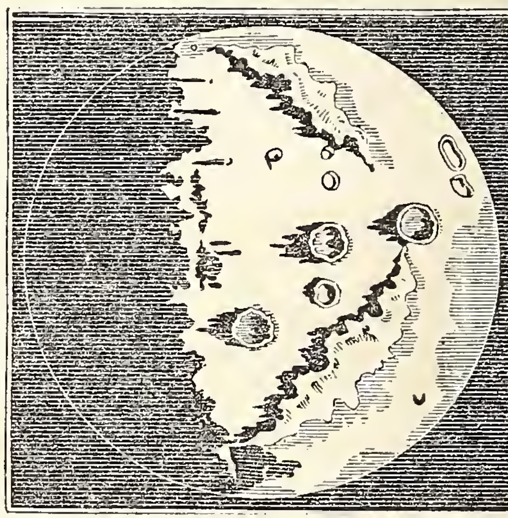
506. *How does the Moon appear through a Telescope?*

Her surface is very rough and uneven, covered with deep valleys and lofty mountains.

[The profile of the Moon is remarkably characterized by inequalities like our mountain ranges. This, indeed, is its most striking features. There are a great number of perfectly isolated conical peaks, or sugar-loaf mountains, springing out of the plains, and also several magnificent *chains* or *ridges*, some of whose peaks are 25,000 feet high. The chain called the APENNINES, represented in the following cut, is not surpassed by any of the ranges of our globe. They are most precipitous on the side toward the plain country, and gradually slope off through thousands of minor peaks on the opposite declivity; thus conforming to what seems to be a *law* among our terrestrial ranges; viz. they are steep, almost precipitous, on one side, and their other is a long slope. See Nichol on the Solar System.]

507. *What proof have we that the Moon's surface is mountainous?*

TELESCOPIC APPEARANCE OF THE MOON.



The line of the *terminator* is very rough and uneven, which would not be the case if her surface was level or smooth.

[See line dividing the illuminated from the dark portion in the annexed cut.]

508. *Have we any other proof?*

The projection of long *shadows*, in a direction opposite the Sun, shows the existence of mountains that intercept the Sun's light.

[These shadows may be seen in the above cut, projected from right to left.]

509. *Can you mention any further evidence of the existence of Mountains in the Moon?*

From New to Full Moon bright spots break out from time to time, just *east* of the terminator, in the dark portion, and grow larger and larger, till they join the illuminated portion, showing them to be the tops of mountains, which reflect the sunlight before it reaches the intervening valleys.

[Specimens of these bright points may be seen in the cut. The writer has often watched them, and seen them enlarge more and more, as the Sun arose and enlightened the sides of the mountains.]

510. *When is the best time to examine the Moon with a Telescope?*

Near the First or Third Quarter.

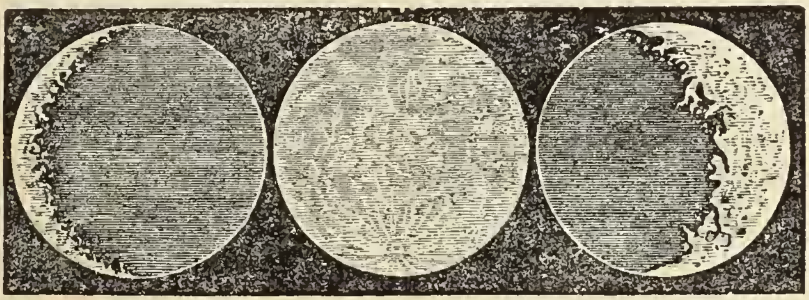
511. *Why is this?*

Because the shadows of objects are then seen at right angles with the line of vision, and to the best advantage; while at Full Moon objects cast no shadows visible to us.

512. *How are the Shadows projected from the Full to the New Moon?*

From east to west.

OLD MOON. FULL MOON. NEW MOON.



[1. The shadows are always projected in a direction opposite the Sun, or toward the dark side of the Moon; and as her eastern limb is dark from the change to the full, and her western from the full to the change, of course the direction of the shadows must be reversed.

2. Suppose a person stationed at a distance directly over the Andes. Before the Sun arose, he would see the tallest peaks enlightened, and as he arose the long shadows of the mountains would extend to the *west*. At noon, however, little or no shadow would be visible; but at sunset they would again be seen stretching away to the *east*. This is precisely the change that is seen to take place with the lunar shadows, except that the *time* required is a lunar day, equal to about 15 of our days, instead of a terrestrial day of 12 hours.]

513. *What is the* FORM *of the Lunar Mountains?*

Some of them are in extensive ranges, while others are of a circular form.

[Great numbers of these circular mountains may be seen with a telescope of moderate power. Through such an instrument the Moon will appear of a yellowish hue, and the circular mountains like drops of thick oil on the surface of water. Two extensive ranges and several of the circular elevations are shown in the cut, page 110.]

514. *What is their estimated* HIGHT?

From three to five miles.

[Almost every common Arithmetic has rules for determining the hight of objects by the length of their shadows; and by applying these rules to the shadows seen upon the Moon's surface, astronomers ascertain the hight of the lunar mountains.]

515. *What is inferred from the* SHAPE *of the Circular Mountains?*

That they are *craters* of immense volcanoes.

516. *Is the Moon surrounded by an* ATMOSPHERE?

It is not certain whether she is or not: if she is, it must be exceedingly thin or rare.

[The substance we call *air* or *atmosphere* is subject to the general law of gravitation. Hence it is most dense at the Earth's surface, and grows rare as we ascend. Inasmuch, therefore, as the general density of the atmosphere of any planet is dependent upon the attracting force of that planet; and the Moon has only about $\frac{1}{73}$d part as much attracting power as the Earth; it follows that her atmosphere, if she has one, ought to be much less dense than ours.]

517. *Has she any* WATER *upon her surface?*

It is thought not, from the fact that it would be converted into steam or vapor, during her long and hot days, and from the fact that no *clouds* are ever seen floating around her.

518. *Was it ever supposed that she had* SEAS *upon her surface?*

It was; but the portions once supposed to be seas, are now found to be only *prairies* or *plains.*

519. *How does the Moon appear through Lord Ross's great Telescope?*

Dr. Scoresby, who examined her through this instrument, states that she appears "like one vast ruin of nature," with numerous volcanoes, and fragments of rock scattered about them in every direction.

520. *What does Dr. Herschel say of the Lunar Volcanoes?*

He believed that he actually saw the *fires* of several that were in active eruption.

[This has not been confirmed by any recent observer, and is therefore somewhat doubtful.]

LESSON XXVI.

ECLIPSES OF THE SUN.

521. *What is an* ECLIPSE?

It is a partial or total *obscuration* or *darkening* of the Sun or Moon, by the intervention of some opake body.

522. *How many kinds of Eclipses are there?*

The first general division is into *Solar* and *Lunar*.

523. *What is a* SOLAR *Eclipse?*

An Eclipse of the *Sun*.

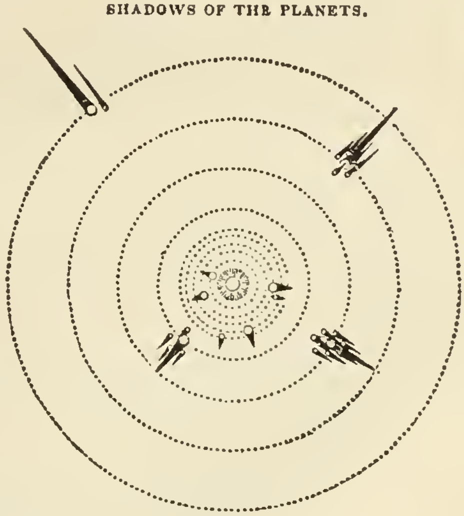
524. *What is a* LUNAR *Eclipse?*

An Eclipse of the *Moon*.

525. *What is the first point to be observed in considering the subject of Eclipses?*

The fact that all the planets, both primary and secondary, cast shadows in a direction opposite the Sun.

SHADOWS OF THE PLANETS.



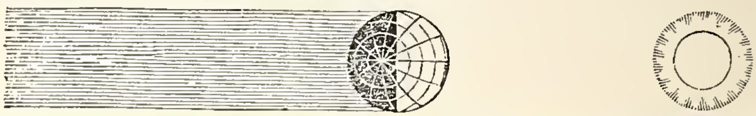
526. *Upon what does the* FORM *and* LENGTH *of these shadows depend?*

Upon the *comparative magnitude* of the Sun and planet, and their *distance* from each other.

527. *What would be the form of the Shadow if the Sun and planet were of a size?*

The shadow would be in the form of a *cylinder*.

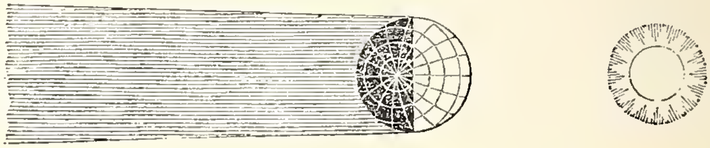
CYLINDRICAL SHADOW.



528. *What would be the form of the Shadow if a planet were* LARGER *than the Sun?*

It would *diverge* or expand from the planet outward.

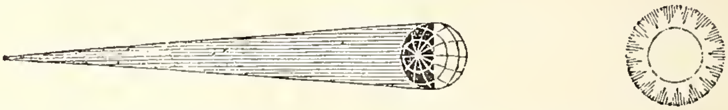
DIVERGING SHADOW



529. *As the planets are much* SMALLER *than the Sun, what must be the form of their Shadows?*

They must converge to a point, taking the shape of a *cone*.

CONVERGING SHADOW.

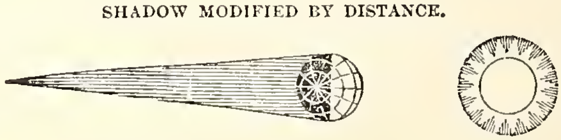


[By observing the cut on the preceding page, the student will see the shadows of the planets all running to a point, in accordance with this principle.]

530. *What effect has the* DISTANCE *of a planet upon the form and length of its Shadow?*

The more distant, the longer its shadow, and the more slender the point of the cone.

SHADOW MODIFIED BY DISTANCE.



[1. In this cut, the Sun and Earth are of the same size as in the one immediately preceding, and yet this shadow is *shorter* and the cone more abrupt than in the other case, simply because the two bodies are here placed nearer each other.

2. By turning again to Question 526, and the cut, you will see that the bodies near the Sun have comparatively short shadows, and the cones terminate quite abruptly; while those more distant have longer and more slender shadows. No primary, however, casts a shadow long enough to reach the next exterior planet.]

531. *What is the* CAUSE *of a Solar Eclipse?*

It is caused by the Moon passing between the Earth and the Sun, and casting her shadow upon the Earth.

532. *At what time of the Moon must they always occur?*

At *New Moon.*

533. *Why is this?*

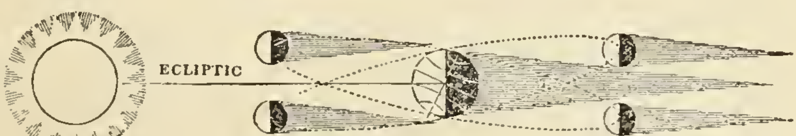
Because she is never between the Earth and the Sun except at the time of her change.

534. *Why do we not have a Solar Eclipse at every New Moon?*

Because the plane of the Moon's orbit is not in the plane of the ecliptic; so that she sometimes passes *above* the Sun, and sometimes *below* him.

NEW MOONS WITHOUT ECLIPSES.

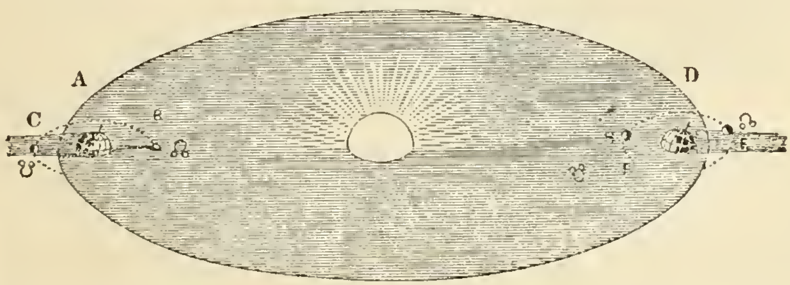
Above the Sun.



Below the Sun.

[Let the line joining the Earth and the Sun represent the plane of the ecliptic. Now as the orbit of the Moon departs from this plane 5° 9′, as shown and illustrated at 461, she may appear either *above* or *below* the Sun at New Moon, as represented in the figure; and her shadow fall above the North Pole or below the South. At such times, then, there can be no eclipse.]

SOLAR ECLIPTIC LIMITS.



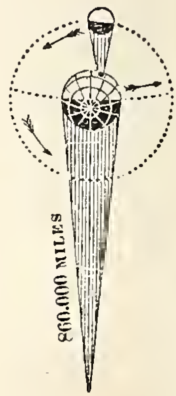
535. *Why do Eclipses of the Sun always come on from the West and pass over Eastward?*

SOLAR ECLIPSE.

Because the Moon, which causes them, revolves from west to east.

[1. In the adjoining cut, the Moon is seen revolving eastward, throwing her shadow upon the Earth, and hiding the western limb of the Sun. In some instances, however, when the eclipse is very slight, it may first appear on the *northern* or *southern* limb of the Sun; that is, the upper or lower side; but even then its *direction* must be from west to east.

2. It will also be obvious from this figure, that the *shadow* of the Moon upon the Earth must also traverse her surface from west to east. Consequently, the eclipse will be visible earlier in the west than in the east.]



536. *Where must the Moon be in her orbit at the time of her change, in order to eclipse the Sun?*

At or near one of her Nodes.

537. *What is the greatest distance at which she may be from either Node, and yet eclipse the Sun?*

About *seventeen degrees* (16° 59′).

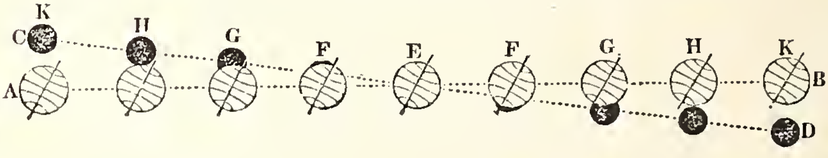
538. *What is this distance called?*

The *Solar Ecliptic Limits.*

[1. This point is illustrated by the last cut on the preceding page. At A the line of the Moon's nodes points directly toward the Sun, so that in passing her ascending node at B, the Moon passes centrally between him and the Earth, and produces a total eclipse. At C, also, the Moon would pass the Earth's shadow centrally, and would be totally eclipsed.

2. At D the case is different. The line of the Moon's nodes points east of the Sun, and she reaches her conjunction at H when seventeen degrees from her descending node at F. There is now no eclipse, as the Moon is too far from her node, and consequently too high above the ecliptic. The distance from F to H represents her *Ecliptic Limits*, within which she must be at her change in order to eclipse the Sun.

THE MOON CHANGING AT DIFFERENT DISTANCES FROM HER NODES.



3. Let the line A B represent the plane of the Earth's orbit, and C D that of the Moon. Now if the change occurred when the Moon was exactly at her node, and the Earth on the *line* of her nodes (as shown at E, where the Moon is supposed to be *beyond* the Earth, and out of sight), the Moon would be in the plane of the ecliptic, and would appear to pass directly over the Sun's center. Such an eclipse would, therefore, be *central*, and either total or annular.

4. If the change took place when the Moon was either side of her node as at F F, her center would be either *above* or *below* the ecliptic, and she would appear to cross the upper or lower part of the *Sun*. The eclipse, therefore, would be partial.

5. At G G the eclipse would be still less; at H H the two disks (Sun and Moon) would seem just to touch each other; and at K K and all points more distant from the nodes there would be no eclipse whatever, as the Moon would seem to pass entirely above or below the Sun. The points H H represent the *Solar Ecliptic Limits.*]

539. *When, therefore, may we expect Eclipses of the Sun?*

Whenever the Moon is within 17° of either Node at the time of her change.

540. *What is meant by the* UMBRA *of the Earth and Moon?*

It is the *dark shadow* cast in a direction opposite the Sun.

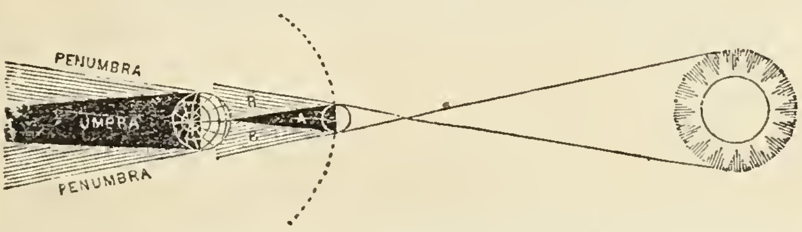
[*Umbra* is a Latin word, signifying a *shade* or *shadow*.]

541. *What is the* PENUMBRA?

It is a *partial shadow* outside the Umbra.

[*Pe-num-bra* is from the Latin *pene*, almost, and *umbra*, a shadow; and signifies *almost a shadow*.]

UMBRA AND PENUMBRA OF THE EARTH AND MOON.



[1. In this cut, the Earth's umbra and penumbra will be readily found by the lettering, while A is the umbra and B B the penumbra of the Moon. The latter is more broad than it should be, owing to the nearness of the Sun in the cut, as it never extends to much over half the Earth's diameter.

2. The student will see at once that solar eclipses can be total only to persons within the umbra; while to all on which the penumbra falls a portion of the Sun's disk will be obscured.]

542. *What is the average* LENGTH *of the Moon's Umbra?*

About 239,000 miles.

[It varies from 221,148 to 252,638 miles, according to the Moon's distance from the Sun. See 526, and cut.]

543. *What is its greatest* DIAMETER *at the distance of the Earth?*

About 170 miles.

[This is when it strikes the Earth *centrally* or perpendicularly to its surface. When it strikes *obliquely*, it covers a much larger surface.]

544. *How large a portion of the Earth's surface may be covered by the Moon's* PENUMBRA?

About 4,393 miles in diameter.

545. *What is a* PARTIAL *Eclipse?*

One in which only part of the Sun or Moon is obscured.

546. *When is an Eclipse* TOTAL?

When the whole disk of the Sun or Moon is darkened.

547. *What is an* APPULSE?

It is when the Sun and Moon, or the Moon and the Earth's shadow, seem just to *touch*, without producing an actual eclipse. (See H H in the cut, page 116.)

548. *At what places on the Earth are Solar Eclipses generally* TOTAL?

At all places within the Moon's Umbra.

549. *Where are they* PARTIAL?

At all places *beyond* the Umbra and *within* the Penumbra.

550. *What is meant by a* CENTRAL *Eclipse of the Sun?*

It is when the Moon changes when *exactly* at one of her Nodes, and appears to pass *centrally* over the Sun's disk.

551. *Are all* CENTRAL *Eclipses of the Sun necessarily* TOTAL?

They are not.

552. *If they are central, but not total, how must the Sun appear?*

Totally obscured, with the exception of a bright *ring*, apparently around a dark body in the center.

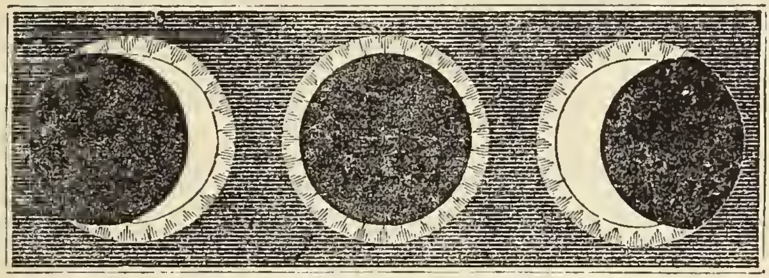
553. *What are such Eclipses called?*

Annular Eclipses.

554. *Why are they called* ANNULAR?

From *annulus*, a *ring*, because the Moon only hides the center of the Sun, and leaves a bright ring unobscured.

PROGRESS OF A CENTRAL ECLIPSE.



555. *When will the next Annular Eclipse visible in the United States occur?*

Sept. 29, 1875.

556. *Why are some Central Eclipses of the Sun* TOTAL *and others* ANNULAR?

Because the apparent magnitude of the Sun and Moon varies as their distances vary. (See 178, and Illustrations.)

TOTAL AND ANNULAR ECLIPSES.

[1. At A the Earth is at her *aphelion*, and the Sun, being at his most distant point, will have his *least* apparent magnitude. At the same time the Moon is in *perigee*, and appears *larger* than usual. If, therefore, she pass centrally over the Sun's disk, the eclipse will be *total.*

2. At B this order is reversed. The Earth is at her *perihelion*, and the Moon in *apogee;* so that the Sun appears *larger* and the Moon *smaller* than usual. If, then, a central eclipse occur under these circumstances, the Moon will not be large enough to eclipse the whole of the Sun, but will leave a ring, apparently around herself, unobscured. Such eclipse will be *annular.*]

557. *What are the effects of a Total Eclipse of the Sun?*

The heavens are shrouded in darkness, so that stars and planets are visible; the temperature declines; the animal tribes become agitated; and a general gloom overspreads the landscape.

[Such were the effects of the great eclipse of June, 1806.]

558. *When will the next Total Eclipse of the Sun, visible in the United States, occur?*

August 7th, 1869.

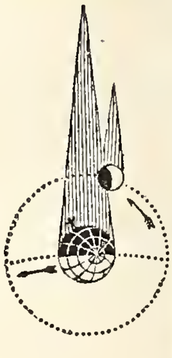
LESSON XXVII.

ECLIPSES OF THE MOON.

559. *What is the cause of* LUNAR *Eclipses?*

The Moon's passing through a portion of the Earth's shadow.

LUNAR ECLIPSE



560. *In what time of the Moon do they always occur?*

At *Full Moon.*

561. *Why is this?*

Because the Moon is always *full* when in opposition to the Sun; and the Earth's shadow being in opposition, the Moon must pass through it when full, if at all.

562. *Why do all Eclipses of the Moon begin on the* EAST, *and pass over Westward, contrary to the direction of a Solar Eclipse?*

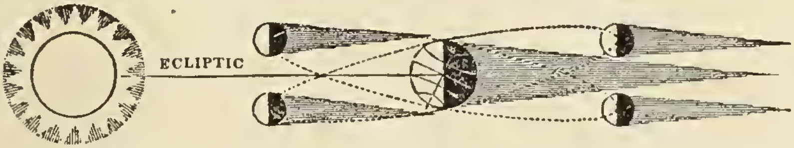
Because, as the Moon revolves eastward, her eastern limb first comes in contact with the Earth's shadow.

[By holding the book up south of him, the student will see at once why the eastern limb of the Moon must be first eclipsed, and why the shadow seems to pass over westward.]

563. *Why have we not a Lunar Eclipse at every Full Moon?*

For the same reason that we have not a Solar Eclipse at every New Moon; namely, because the Moon's orbit is not in the plane of the ecliptic, where the Earth's shadow lies.

NEW AND FULL MOONS WITHOUT ECLIPSES.



[Here it will be seen that as the Moon's orbit departs 5° 9′ from the plane of the ecliptic, she may pass either above or below *the Earth's shadow*, and therefore not be eclipsed by it.]

564. *Where must the Moon be in her orbit, at the time of her opposition, in order to be eclipsed?*

At or near one of her Nodes.

565. *What are her Ecliptic Limits?*

About twelve degrees (11° 25′ 40″).

566. *What is the average* LENGTH *of the Earth's Shadow?*

About 860,000 miles. (See cut, page 116.)

[Its length varies from 842,217 to 871,262 miles, according to the Earth's distance from the Sun. See 113, and cut.]

567. *What is its average* BREADTH *at the distance of the Moon?*

About 6,000 miles.

[This breadth also varies from 5,232 to 6,365 miles.]

568. *How long, then, may an Eclipse of the Moon last?*

If central, it may last *four hours.*

569. *What is the natural progress of a Lunar Eclipse?*

As the Moon enters the Earth's *Penumbra*, she loses a portion of the Sun's light, and begins to grow pale or dusky, till at length she enters the *Umbra*, and is really eclipsed.

570. *Can an Eclipse of the Moon ever be* ANNULAR?

It cannot.

571. *Why not?*

Because the diameter of the Earth's shadow, where the Moon passes it, is always greater than the diameter of the Moon.

572. *What is the greatest and least number of Eclipses that can ever occur in one year!*

There can never be less than *two*, nor more than *seven*.

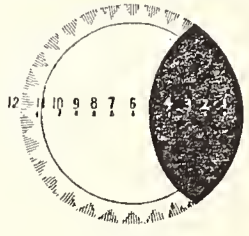
573. *What is the most common number?*

Four.

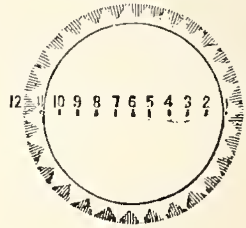
574. *How do astronomers record the* EXTENT *of Solar and Lunar Eclipses?*

By dividing the diameters of the Sun and Moon into twelve equal parts, called *Digits*, and observing how many of these parts are eclipsed.

FIVE DIGITS ECLIPSED.



TWELVE DIGITS.



575. *How were Eclipses regarded by the Ancients?*

With amazement and fear; as supernatural events, indicating the displeasure of the gods.

576. *What use did Columbus make of this Superstition?*

When the inhabitants of St. Domingo refused to allow him to anchor, in 1502, or to furnish him supplies, he told them the Great Spirit was offended at their conduct, and was about to punish them. In proof, he said the Moon would be darkened *that very* *night*, for he knew an eclipse was to occur. The artifice led to a speedy supply of his wants.

LESSON XXVIII.

SATELLITES OF JUPITER, ECLIPSES, ETC.

577. *How many Moons has Jupiter?*

Four.

578. *Are they easily seen?*

They are with a spy-glass or telescope, but not with the naked eye. (See note after 405.)

[It is said, however, that one or two of them may occasionally be seen with the naked eye; but such occasions and such eyes will rarely be met with.]

579. *Who first discovered them?*

Galileo, the inventor of the telescope.

580. *How are they distinguished?*

As *first*, *second*, *third*, and *fourth*, according to their distances from their primary.

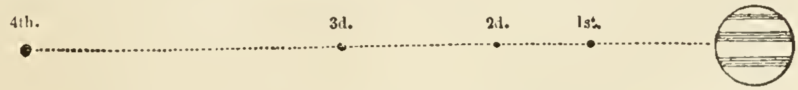
581. *What is their* SIZE *or* MAGNITUDE?

They are all a little larger than our Moon, except the second, which is a trifle less.

582. *How are they situated as to* DISTANCE *from Jupiter?*

The first is about the distance of our Moon, and the others respectively about two, three, and five times as far off.

COMPARATIVE DISTANCES OF JUPITER'S MOONS.



583. *In what time do they revolve about their Primary?*

From 1 day 18 hours to 17 days; according to their respective distances.

[Though the fourth satellite is 1,164,000 miles from Jupiter, or about five times the distance of our Moon, she revolves around her primary in seventeen days!]

584. *Why do the Moons of Jupiter* REVOLVE *so rapidly?*

In order to counterbalance his powerful centripetal force or attraction, and keep the satellites from falling to his surface.

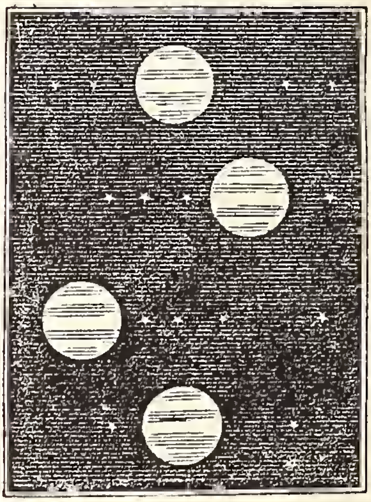
585. *How are the* ORBITS *of these Moons situated?*

They are all *in* or *near* the plane of his equator. (See representation in the last cut).

586. *How would this place them with respect to the* ECLIPTIC?

As Jupiter's orbit and axis are but slightly inclined, his equator nearly coincides with the ecliptic; and if his satellites revolve near the plane of his *equator*, they must also be near the *ecliptic.*

TELESCOPIC VIEWS OF THE MOONS OF JUPITER.



587. *How do these Satellites usually appear to be situated?*

At different distances; some on one side of the primary, and some on the other.

588. *What is their apparent motion?*

They seem to oscillate like a pendulum, from their greatest elongation on one side, to their greatest elongation on the other.

[If we could look down perpendicularly upon the ecliptic, we should see these satellites revolving in apparent *circles;* but as we are in or near the *plane* of the ecliptic, which is the plane of their orbit, they seem merely to pass to and from the plane.]

589. *What is the* FORM *of the Orbits of these Satellites?*

They are very nearly circular.

[This fact is ascertained by observing that their greatest elongation is nearly the same both east and west at every revolution; whereas, if their orbits were very elliptical, their greatest elongations would vary. See Question 247, and Notes.]

590. *In what* DIRECTION *do they revolve?*

From west to east, or in the direction their primary revolves, both upon his axis and in his orbit.

[See the directions as indicated by the arrows in the next cut.]

591. *Have they a revolution around their respective Axes?*

They are supposed to revolve once upon their axes during every revolution around their primary, as is the case with our own satellite.

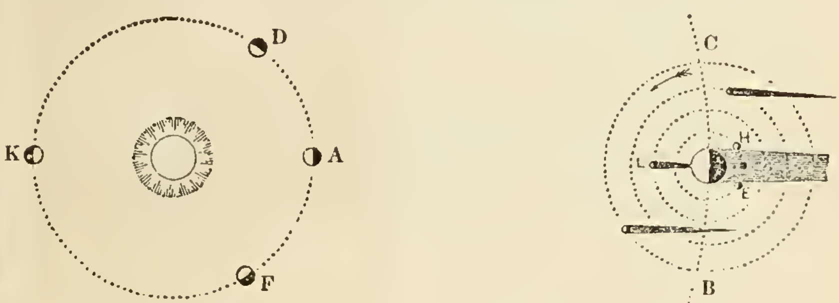
592. *Are Jupiter's Moons always visible?*

They are not. Sometimes only one or two can be seen. (See the lower figure in the opposite cut.)

593. *Why is this?*

Because, as their orbits lie near the plane of Jupiter's orbit, they have to pass his broad shadow, and be totally *eclipsed* at every revolution.

ECLIPSES OF JUPITER'S MOONS.



[1. In this cut we have a *perpendicular* view of the orbits of Jupiter's satellites, and they appear like circles. The first Moon is in an *eclipse*.

2. To a person on the Earth at A, the fourth Moon would seem to pass and repass from B to C; and so with the other three, according to their respective distances.]

594. *Are there no exceptions to the total eclipse of these Satellites at every revolution?*

There is one exception. As the fourth satellite departs about 3° from the plane of Jupiter's orbit, and is quite distant, it sometimes passes *above* or *below* the shadow, and escapes eclipse. But such escapes are not frequent.

595. *Do these Satellites ever eclipse Jupiter?*

Their shadows are often thrown upon his bright disk, and may be seen like small round ink-spots, traversing it from side to side.

[The second satellite is thus eclipsing Jupiter in the preceding cut.]

596. *What kind of an Eclipse is it upon Jupiter, when the shadow of a Satellite falls upon the primary?*

An Eclipse of the Sun, or *Solar Eclipse.*

597. *How many Eclipses, visible from Jupiter, take place every month?*

About forty.

598. *When a Satellite goes into Jupiter's shadow, what is it called?*

Its *Immersion;* because it is *immersed*, hid, or buried in the shadow.

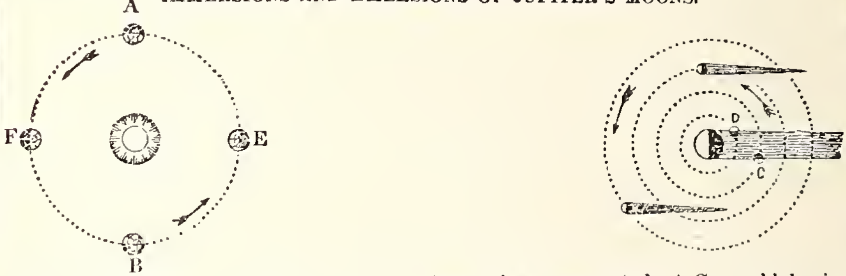
599. *What is its coming out of the shadow called?*

Its *Emersion*, because it *emerges* or comes out.

600. *Can these Immersions and Emersions always be seen?*

They cannot; as the position of the Earth in her orbit is sometimes unfavorable for such observations.

IMMERSIONS AND EMERSIONS OF JUPITER'S MOONS.



[If the Earth were at A in the cut, the *immersion*, represented at C, would be invisible; and if at B, the *emersion* at D could not be seen. So, also, if the Earth were at F, neither could be seen; as Jupiter and all his attendants would be directly beyond the Sun, and would be hid from view.]

601. *How may the system of Jupiter and his Satellites be regarded?*

As a miniature representation of the Solar System;

and as furnishing triumphant evidence of the truth of the Copernican theory.

602. *In what other light may it be viewed?*

As a great NATURAL CLOCK, keeping absolute time for the whole world.

603. *How is time marked by this system?*

By the *immersions* and *emersions* of the satellites.

604. *What use can we make of the time thus denoted?*

We may ascertain the longitude of any place upon the Earth's surface.

[1. By long and careful observations upon these satellites, astronomers have been able to construct tables, showing the exact time when each immersion and emersion will take place, at Greenwich Observatory, near London.

2. Suppose the tables fixed the time for a certain satellite to be eclipsed at 12 o'clock at Greenwich, but we find it to occur at 9 o'clock, for instance, by our time. This would show that our time was three hours *behind* the time at Greenwich; or in other words, that we were three hours, or 45° *west* of Greenwich. If our time was *ahead* of Greenwich time, it would show that we were *east* of that meridian, to the amount of 15° for every hour of variation. See Question 270 to 274, page 59.]

605. *What great discovery was made by observations upon the Eclipses of Jupiter's Moons?*

The progressive motion and velocity of light.

[This discovery may be illustrated by again referring to the opposite cut. In the year 1675 it was observed by Roemer, a Danish astronomer, that when the Earth was nearest to Jupiter, as at E, the eclipses of his satellites took place 8 minutes 13 seconds *sooner* than the mean time of the tables; but when the Earth was farthest from Jupiter as at F, the eclipses took place 8 minutes and 13 seconds *later* than the tables predicted: the entire difference being 16 minutes and 26 seconds. This difference of time he ascribed to the progressive motion of light, which he concluded required 16 minutes and 26 seconds to cross the Earth's orbit from E to F.]

606. *What is the estimated Velocity of Light?*

About 200,000 miles per second (192,697).

[16 m. 26 s. = 986 s. If the radius of the Earth's orbit be 95 millions of miles, the diameter must be twice that, or 190 millions. Divide 190,000,000 miles by 986 seconds, and we have $192.697\frac{379}{439}$ miles as the progress of light in each second. At this rate, light would pass nearly eight times around the globe at every tick of the clock; or nearly 500 times every minute!]

607. *Is there any thing more rapid than Light?*

Electricity is supposed to move about *one-third faster;* or near 300,000,000 miles per second.

LESSON XXIX.

SATELLITES OF SATURN, HERSCHEL, AND NEPTUNE.

608. *How many Moons has Saturn?*

Eight. (See 420, and cut, page 9.)

609. *Are they visible to the naked eye?*

They are not; and can only be seen with telescopes of considerable power.

610. *When is the best time to observe them?*

When Saturn is at his *equinoxes*, and his rings nearly invisible.

SATELLITES OF SATURN.

[In January, 1849, the author saw five of these satellites, as represented in the adjoining cut. The rings appeared only as a line of light, extending each way from the planet, and the satellites were in the direction of the line, at different distances, as here represented. See Note, after 420.]

611. *What is the* Form *and* Position *of their Orbits?*

They are nearly circular; and all except the eighth revolve in the plane of the rings. (See the above cut.)

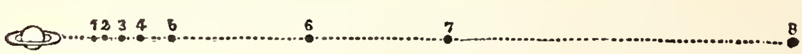
612. *In what direction do they revolve?*

From west to east, or with the planet and his rings.

613. *What are their* Distances?

From 123,000 to 2,366,000 miles.

COMPARATIVE DISTANCE OF THE MOONS OF SATURN.



614. *What are their Periods of Revolution?*

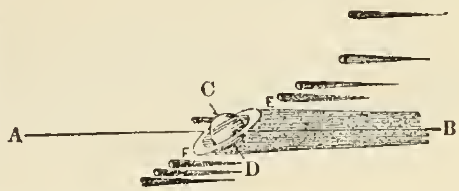
From 22 hours to 79 days, according to their respective distances.

615. *Is any thing known of the* Magnitude *of Saturn's Moons?*

The most distant is the largest, supposed to be about the size of Mars; and the remainder seem to grow smaller, according to their respective distances.

616. *Do they suffer any* Eclipses?

Very seldom, except when the rings are seen edgewise.



[1. Let the line A B represent the plane of the planet's orbit, C D his axis, and E F the plane of his rings. The satellites being in the plane of the rings, will revolve *around* the shadow of the primary, instead of passing through it and being eclipsed.

2. At the time of his equinoxes, however, when the rings are turned toward the Sun (see A and E, cuts, page 91), they must be in the center of the shadow on the opposite side; and the Moons, revolving in the plane of the rings, must pass through the shadow at every revolution. The eighth, however, may sometimes escape, on account of his departure from the plane of the rings, as shown in the cut.]

617. *Do these Satellites revolve upon their respective Axes?*

The eighth, which has been studied more than all the rest, is known to revolve once upon its axis during every periodic revolution; from which it is inferred that they all revolve on their respective axes in the same manner.

SATELLITES OF HERSCHEL

618. *How many Satellites has the planet* Herschel?

Six.

[He is generally allowed to have six, upon the authority of Sir Wm. Herschel, and his son, Sir John Herschel. Only three, however, have ever been seen by any other observers, and seldom over two.]

619. *What are their* Distances?

From 224,000 to 1,500,000 miles.

620. *Their* Periodic Times?

From 1 day, 21 hours, to 117 days, according to their respective distances.

621. *What remarkable peculiarities do these Satellites exhibit?*

Their orbits are nearly perpendicular to the ecliptic, and they revolve *backward*, or from east to west, contrary to all the other motions of our planetary system.

622. *Have we any other information respecting these Moons?*

None; except that they revolve in orbits nearly circular, and are described by Dr. Herschel as "the most difficult objects to obtain a sight of of any in our system."

SATELLITE OF NEPTUNE.

623. *When and by whom was this Satellite discovered?*

By Mr. Lassell, of Liverpool, England, October 10, 1846.

624. *What is its* DISTANCE *from Neptune?*

About 230,000 miles, or near the distance of our Moon.

625. *What is its* PERIODIC TIME?

Five days and twenty-one hours.

[We have here another illustration of the great law of planetary motion explained on page 48. So great is the attractive power of Neptune. that to keep a satellite, at the distance of our Moon, from falling to his surface, it must revolve some five times as swiftly as she revolves around the Earth. The centripetal and centrifugal forces must be balanced in all cases.]

626. *Are there any suspicions that Neptune has other Satellites?*

Professor Bond, of Cambridge, Mass., states that he has at times been quite confident of seeing a *second* satellite.

627. *What general fact has been arrived at with respect to the Secondary Planets?*

That the laws of gravitation and planetary motion, discovered by Newton and Kepler, extend to and prevail among all the secondaries.

LESSON XXX.

OF TIDES.

628. *What are Tides?*

The alternate rising and falling of the waters of the ocean, at regular intervals.

629. *What is meant by* FLOOD *and* EBB *Tides?*

When the waters are *rising*, it is called *Flood Tide;* and when they are *falling*, *Ebb Tide.*

630. *What is meant by* High *and* Low *Tide?*

When the waters have reached the highest and lowest points to which they usually go.

631. *Is this elevation and depression uniform as to its amount?*

It is not: some high tides are much higher and others much lower than the average.

632. *What are these extraordinary High Tides called?*

Spring Tides.

633. *What are the remarkably Low Flood Tides called?*

Neap Tides.

634. *How often does the Tide ebb and flow?*

Twice every day.

[That is, we have two ebb and two flood tides every twenty-four hours, nearly.]

635. *What is the* CAUSE *of the Tides?*

NO TIDE.

The attraction of the Sun and Moon upon the waters of the ocean.

[In this figure, the Earth is represented as surrounded by water, in a state of rest or equilibrium, as it would be were it not acted upon by the Sun and Moon.]

636. *What should we suppose would be the natural effect of the Moon's attraction?*

To produce a single tide-wave on the side of the Earth toward the Moon.

ONE TIDE-WAVE.

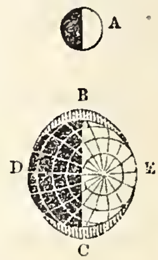
[1. In this cut, the Moon is shown at a distance above the Earth, and attracting the waters of the ocean so as to produce a high tide at A. But as the Moon makes her apparent westward revolution around the Earth but once a day, the simple raising of a flood tide on the side of the Earth toward the Moon, would give us but one flood and one ebb tide in twenty-four hours; whereas it is known that we have two of each.

2. "The tides," says Dr. Herschel, "are a subject on which many persons find a strange difficulty of conception. That the Moon, by her attraction, should heap up the waters of the ocean under her, seems to many persons very natural. That the same cause should, at the same time, heap them up on the opposite side of the Earth (as at B in the figure), seems to many palpably absurd. Yet nothing is more true."]

637. *Does the Moon cause but one Tide-Wave upon the globe?*

She produces *two* at the same time; one nearly under her, and the other on the opposite side of the Earth.

TWO TIDE-WAVES.



[In this cut we have a representation of the tide-waves as they actually exist, except that their hight, as compared with the magnitude of the Earth, is vastly too great. It is designedly exaggerated, the better to illustrate the principle under consideration. While the Moon at A attracts the waters of the ocean, and produces a high tide at B, we see another high tide at C on the opposite side of the globe. At the same time it is low tide at D and E.]

638. *In what direction do these Tide-Waves move?*

From east to west, or as the Moon appears daily to revolve.

[These four tides, viz. two high and two low, traverse the ocean from east to west every day, which accounts for both a flood and an ebb tide every twelve hours.]

639. *How do you account for the Tide-Wave on the side of the Earth opposite the Moon?*

It is due principally to the *difference* between the Moon's attraction on different sides of the Earth.

[1. The student may do well to review the subject of gravitation, 195, 206, and 207.

2. The diameter of the Earth amounts to about $\frac{1}{30}$th of the Moon's distance, so that by the rule, Question 206, the difference in her attraction on the side of the Earth toward her, and the opposite side, would be about $\frac{1}{15}$th. The attraction being stronger at B (in the last cut) than at the Earth's center, and stronger at her center than at C, would tend to *separate* these three portions of the globe, giving the waters an elongated form, and producing two opposite tide-waves, as shown in the cut.]

640. *What other influence helps to produce the Tide-Wave opposite the Moon?*

The revolution of the Earth around the common center of gravity between her and the Moon during every lunation.

641. *What is meant by the Center of Gravity?*

The point between them where they would exactly balance each other if connected by a rod, and poised upon a fulcrum.

CENTER OF GRAVITY BETWEEN THE EARTH AND MOON.

642. *Where is the Center of Gravity between the Earth and Moon situated?*

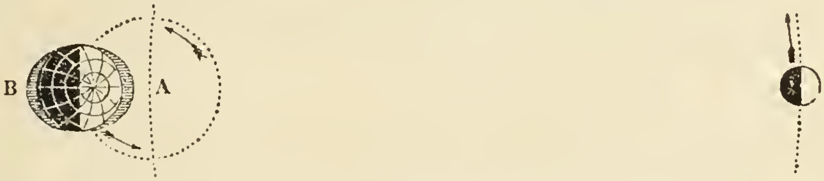
About 6,000 miles from the Earth's center.

[This point is represented at A in the above cut, and also in the one following. We give 6,000 miles as the answer to the question, on the authority of Furguson. See his Note to Art. 298, London edition, 1764.]

643. *How does the Revolution of the Earth and Moon around the common Center of Gravity between them, help to produce a Tide-Wave opposite the Moon?*

By generating an increased centrifugal force on that side of the Earth.

CAUSE OF HIGH TIDE OPPOSITE THE MOON.



[1. The point A represents the center of gravity between the Farth and Moon; and as it is this point which traces the regular curve of the Earth's orbit, it is represented in the arc of that orbit, while the Earth's center is 6,000 miles one side of it. Now the law of gravitation requires that while both the Moon and Earth revolve around the Sun, they should also revolve around the common center of gravity between them, or around the point A. This would give the Earth a *third revolution*, in addition to that around the Sun and on her axis. The small circles show her path around the center of gravity, and the arrows her direction.

2. This motion of the Earth would slightly increase the centrifugal tendency at B, and thus help to raise the tide-wave opposite the Moon. But as this motion is slow, corresponding with the revolution of the Moon around the Earth, the centrifugal force could not be greatly augmented by such a cause.]

644. *Which attracts the Earth most powerfully, as a whole, the Sun or the Moon?*

The Sun.

645. *Which contributes most to the production of the Tides?*

The Moon.

646. *Why is this?*

On account of her *nearness*, which makes a great difference in her attraction on different sides of the Earth.

[1. It must be remembered that tides are the result, not of the attraction of the Sun and Moon upon our globe *as a whole*, but of that *difference* in their attracting forces, caused by a difference in the *distance* of the several parts. See Question 639, &c.

2. The difference in the distance of two sides of the Earth from the Moon is $\frac{1}{30}$th of the Moon's distance; as $240,000 \div 8,000 = 30$; while the difference, as compared with the distance of the Sun, is only $\frac{1}{11,875}$th, as $95,000,000 \div 8,000 = 11,875$.]

647. *What is the comparative influence of the Sun and Moon in causing Tides?*

As *one* to *three;* the Moon contributing three times as much as the Sun.

648. *Does Flood Tide occur at the same hour each successive day?*

It does not.

649. *What variation is there?*

It happens about 50 minutes later.

650. *Why is this?*

Because the Moon, which causes the tides, is revolving eastward, and comes to the meridian 50 minutes later each successive day.

[As the two tide-waves are opposite each other, if the one next the Moon is later, the other also must be, as is found to be the case.]

651. *What is the Time between two successive High Tides?*

Twelve hours and twenty-five minutes.

652. *Is it Flood Tide when the Moon is on the Meridian?*

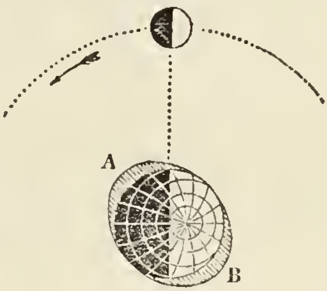
It is not.

653. *Why is it not?*

Because the waters do not at once yield to the impulse of the Moon's attraction, but continue to rise after she has passed over.

654. *How far is the Flood Tide behind the Moon?*

TIDE-WAVES BEHIND THE MOON.



In the open sea it is generally about three hours, or 45° behind.

[In the cut the Moon is on the meridian, but the highest point of the wave is at A, or 45° east of the meridian; and the corresponding wave on the opposite side at B is equally behind.]

655. *Do any other causes affect the time of High Tide?*

It is affected by *winds*, and by the situation of different places.

[If a place is situated on a large bay, with but a narrow opening into the sea, the tide will be longer in rising, as the bay has to fill up through a narrow gate. Hence it is not usually high tide at New York till eight or nine hours after the Moon has passed the meridian.]

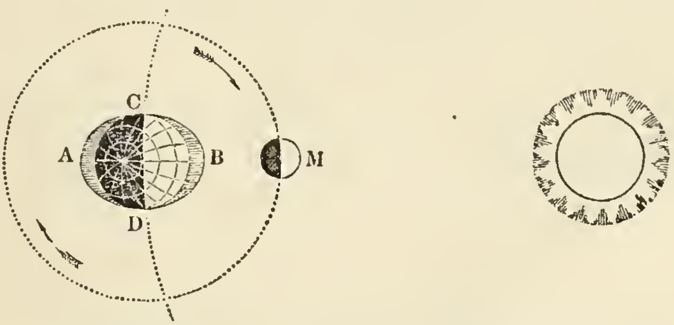
LESSON XXXI.

OF SPRING AND NEAP TIDES.

656. *What is the cause of the* Spring Tides?

The combined influence of the Sun and Moon.

CAUSE OF SPRING TIDES.



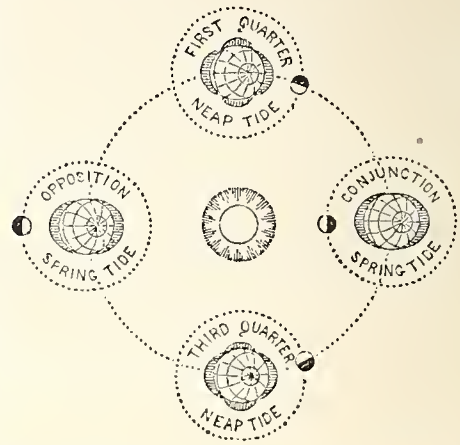
[1. Here the Sun and Moon, being in conjunction, unite their forces to produce an extraordinary tide. The same effect follows when they are in opposition; so that we have two spring tides every month; namely, at New and Full Moon.

2. If the tide-waves at A and B are one-third *higher* at the Moon's quadrature than usual, those of C and D will be one-third *lower* than usual.]

657. *What is the cause of the* NEAP TIDES?

The Sun and Moon acting *against* each other.

SPRING AND NEAP TIDES.



[1. On the right side of the cut the Sun and Moon are in *conjunction*, and unite to produce a *spring tide*.

2. At the First Quarter their attraction acts at right angles, and the Sun, instead of contributing to the lunar tide-wave, detracts from it to the amount of his own attractive force. The tendency to form a tide of his own, as represented in the figure, reduces the Moon's wave to the amount of one-third. See

3. At the Full Moon she is in *opposition* to the Sun, and their joint attraction acting again in the same line, tends to elongate the fluid portion of the Earth, and a second *spring tide* is produced.

4. Finally, at the Third Quarter the Sun and Moon act *against* each other again, and the second neap tide is the result. Thus we have two spring and two neap tides during every lunation; the former at the Moon's syzyges, and the latter at her quadratures.]

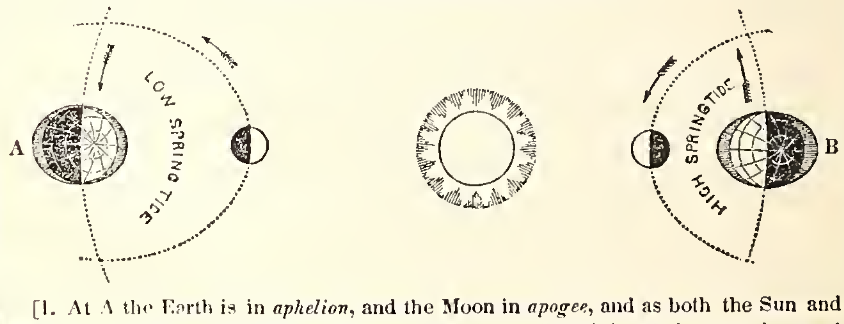
658. *Are all Spring Tides alike as to their elevation?*

They are not: some are much higher than others.

659. *What is the cause of this variation?*

The variation in the *distances* of the Sun and Moon.

VARIATIONS IN THE SPRING TIDES.



[1. At A the Earth is in *aphelion*, and the Moon in *apogee*, and as both the Sun and Moon are at their greatest distance, the Earth is least affected by their attraction, and the spring tides are proportionally low.

2. At B the Earth is in *perihelion*, and the Moon in *perigee ;* so that both the Sun and Moon exert their greatest influence upon our globe, and the spring tides are highest, as shown in the figure. In both cases the Sun and Moon are in conjunction, but the variation in the *distances* of the Sun and Moon causes variations in the spring tides.]

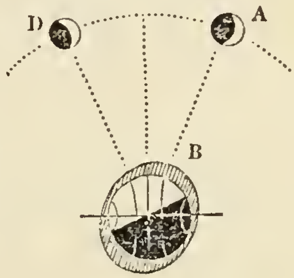
660. *What other general variation of the Tides has been noticed?*

That in Winter and Summer every alternate tide is higher than the intermediate one.

661. *What is the cause of this?*

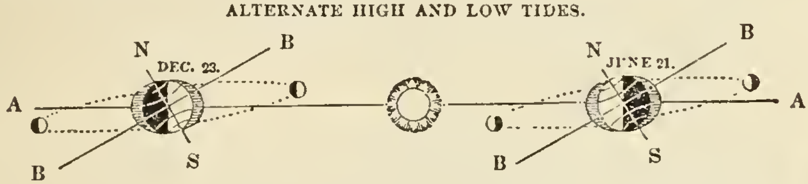
It is owing to the greater declination of the Sun and Moon.

TIDES AFFECTED BY DECLINATION.



[1. At the time of the equinoxes, the Sun being over the equator, and the Moon within 5½° of it, the crest of the great tide-wave will be on the equator; but as the Sun and Moon decline south to A, one tide-wave forms in the south, as at B, and the opposite one in the north, as at C. If the declination was *north*, as shown at D, the order of the tides would be reversed. This subject may be still further illustrated by the following diagram:

ALTERNATE HIGH AND LOW TIDES.



2. Let the line A A represent the plane of the *ecliptic*, and B B the *equinoctial.*

3. On the 21st of June the day tide-wave is north, and the evening wave south, so that the tide following about three hours after the Sun and Moon, will be higher than the intermediate one at 3 o'clock in the morning.

4. On the 23d of December, the Sun and Moon being over the southern tropic, the highest wave in the southern hemisphere will be about 3 o'clock P. M., and the lowest about 3 o'clock A. M.; while at the north this order will be reversed. It is on this account that in high latitudes every alternate tide is higher than the intermediate ones, the evening tides in Summer exceeding the morning tides, and the morning tides in Winter exceeding those of evening.]

662. *To what other variations are the Tides subject?*

They are often hastened or retarded, and increased or diminished, by *strong winds.*

663. *What is the cause of the great variation of the same Tides in different places?*

In some places the tide-wave is pressed into narrow bays or channels, which makes it rise much higher than at other places.

[The average elevation of the tide at several points on our coast is as follows:

Cumberland, head of the Bay of Fundy	71 feet.
Boston	11½ "
New Haven	8 "
New York	5 "
Charleston, S. C.	6 " .]

664. *Have Inland Seas and Lakes any Tides?*

None that are perceptible.

665. *Why is this?*

Because they are too small, compared with the whole surface of the globe, to be sensibly affected by the attraction of the Sun and Moon.

666. *How is the subject of the Tides generally regarded?*

As a difficult one to be fully understood and explained.

[*La Place*, the great French mathematician and astronomer, pronounced it one of the most difficult problems in the whole range of celestial mechanics.]

667. *Is it likely that the* Atmosphere *has its Tides as well as the Waters?*

It is probable that it has, though we have no means as yet for definitely ascertaining the fact.

LESSON XXXII.

OF COMETS.

668. *What are* Comets?

They are a singular class of bodies, belonging to the Solar System, distinguished for their long trains of light, their various shapes, and the great eccentricity of their orbits.

669. *From what is the term* Comet *derived?*

From the Greek word *coma*, which signifies *hair;* on account of the bearded or hairy appearance of some comets.

670. *Are Comets* SELF-LUMINOUS, *or* OPAKE?

They are known to be opake, from the fact that they sometimes exhibit *phases*, which show that they shine only by reflection.

671. *How are Comets usually distinguished one from another?*

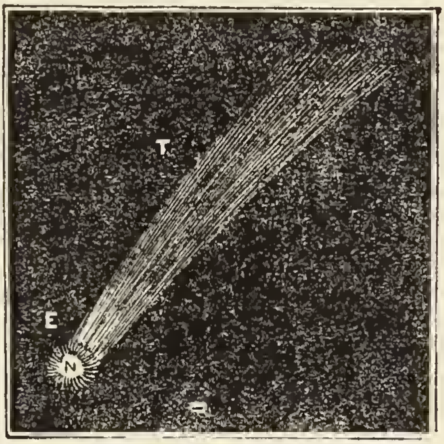
By the date of their appearance, or by a specific name given to them.

[Thus we have the comets of 1585, 1680, 1811, &c.; and also *Halley's* Comet, *Encke's* Comet, *Biela's* Comet, &c.]

672. *What are the principal parts of a Comet?*

The *nucleus*, the *envelope*, and the *tail.*

GREAT COMET OF 371 BEFORE CHRIST.



673. *What is the* NUCLEUS?*

It is the most dense or solid portion, sometimes called the *head.* (See N in the cut.)

674. *What is the* ENVELOPE?†

A thin misty wrapper or covering surrounding the nucleus. (See E in the cut.)

675. *What is the* TAIL *of a Comet?*

An expansion or elongation of the envelope, extending off in one direction from the nucleus. (See T in the cut.)

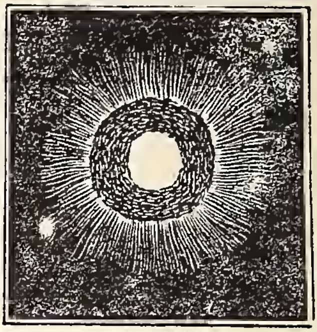
676. *Have all Comets these three parts?*

* NU'-CLE-US, the *kernel* or *nut;* the central part of any body about which matter is collected. The plural of this term is *nu-cle-i.*

† EN-VEL'-OPE, a wrapper or inclosing covering.

They have not. Some have a nucleus and no envelope; some no perceptible nucleus; and others a nucleus and envelope, but no tail.

COMET OF 1585.



[A comet that appeared in 1585 had simply an envelope, as shown in the cut. Encke's comet is another of this kind. See cut, page 143. In 1682 one was seen as round and bright as Jupiter, without even an envelope. But these are rare exceptions to the general character of comets.]

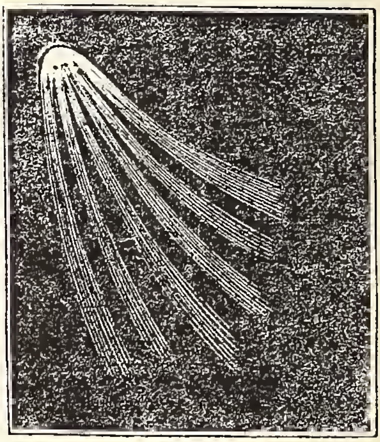
677. *How are the Tails of Comets usually situated?*

They extend in a direction opposite the Sun.

[This is true, not only when going toward tho Sun, but also when going from him. See cut upon the opposite page.]

678. *What is their usual* FORM?

COMET OF 1744.



They assume a great variety of shapes: some appearing like an enormous *fan;* others like a long *sword* or *saber;* but all curved more or less, and concave toward the regions from which they come.

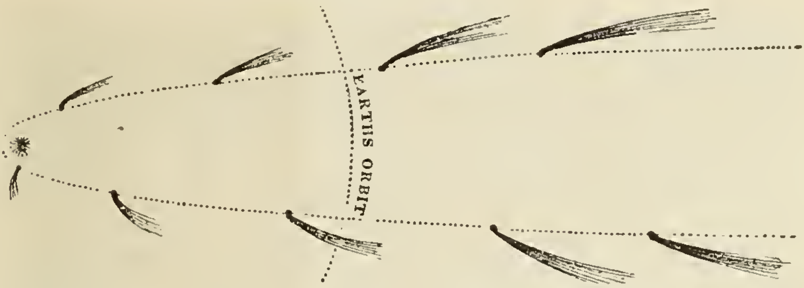
[The comet of 1744. represented in this cut, excited great attention and interest. It exhibited no train till within the distance of the orbit of Mars from the Sun; but early in March it appeared with a tail divided into six branches, all diverging, but curved in the same direction. Each of these tails was about 4° wide, and from 30° to 44° in length. The edges were bright and decided, the middle faint, and the intervening spaces as dark as the rest of the firmament, the stars shining in them. When circumstances were favorable to the display of this remarkable body, the scene was striking and magnificent, almost beyond description. Milner's "Tour through Creation."]

679. *What is the* FORM *of their* ORBITS?

They are generally very elliptical.

[The form of a comet's orbit is represented on the opposite page.]

ORBIT OF A COMET.



[Here it will be seen that the orbit is very eccentric, that the perihelion point is very near the Sun, and the aphelion point very remote. See cuts, pages 2 and 30.]

680. *What effect has this Eccentricity upon the motion of Comets?*

It makes a great difference in their velocity in different parts of their orbits. (See first cut, page 70, and Note.)

681. *What can you say of their* MOTIONS *when near the Sun?*

When passing their perihelion their velocity is sometimes inconceivably rapid.

[1. The comet that appeared in 1472 described an arc of 120° in the heavens in a single day. That of 1680 moved at the rate of 1,000,000 miles an hour!

2. How so light a body can be made to pass through space with such velocity is inconceivable; but we should remember that the space through which they pass is not filled with air, like the regions of our globe, but is utterly void or empty.]

682. *What effect has the change of position upon their appearance?*

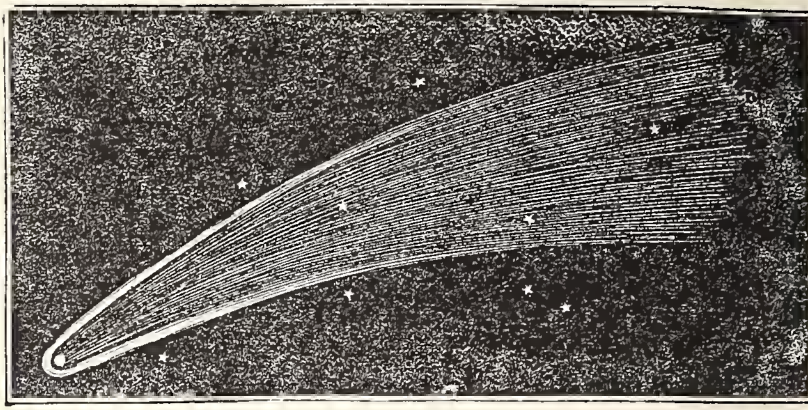
Their tails usually increase both in length and breadth as they approach the Sun, and contract as they recede from him.

[This elongation and expansion, however, may be merely *apparent*. As the comet approaches or retires from the region of the planets, their heads are nearly toward the Earth; but when within the orbit of Jupiter, or about the Sun, we often have a side view of them, under which circumstances they would, of course, appear much larger. By observing the last cut, the student will easily see how a comet might *contract* as it approaches the Sun, as it seems to in the cut, and yet appear much larger when in his neighborhood, than when first seen at a distance.]

683. *What other peculiarity has been noticed?*

The tail of the comet of 1811 is said to have expanded *suddenly* to a great distance.

GREAT COMET OF 1811.



684. *How are the Orbits of Comets situated with respect to the Ecliptic?*

They approach the Sun from every point of the heavens, all around and on both sides of the ecliptic.

[Some comets seem to come up from the immeasurable depths below the ecliptic, and having passed their perihelion, plunge off again into space, and are lost for ages in the ethereal void. Others appear to come down from the zenith of the universe, and having passed around the Sun, reascend far above all human vision.]

685. *Is any thing known of their* TEMPERATURES?

Only that some approach very near the Sun, and must therefore become very hot.

[The comet of 1680 came within 130.000 miles of the Sun's surface, and must have received 28,000 times the light and heat which the Earth receives from the Sun—a heat more than 2,000 times greater than that of red-hot iron!]

686. *What can be said of the* SIZE *of Comets?*

Their *nuclei* or *heads* are comparatively small, being only from 33 to 2,000 miles in diameter. Their *tails* are often of enormous length.

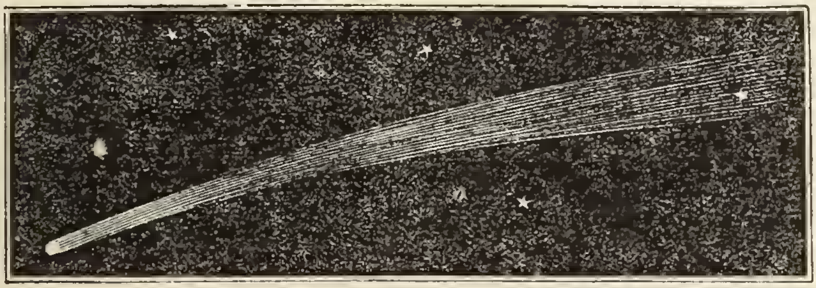
[1. The comet of 371 B. C. (page 139) had a tail 60° long, covering one-third part of the visible heavens. It was estimated at 140 millions of miles in length.

2. The comet of 1680 was 70° in length, estimated at 100 millions of miles. Though its head set soon after sundown, its tail continued visible all night.

3. In 1618 a comet appeared which was 104° long. Its tail had not all risen when its head had reached the middle of the heavens.

4. The comet of 1813 was 60°, or 130,000,000 miles in length.]

GREAT COMET OF 1843.



687. *Is any thing known of the* PHYSICAL NATURE *of Comets?*

They are known to be exceedingly light vapor or gas.

688. *How is this known?*

From the fact that the fixed stars have been seen through their densest portions.

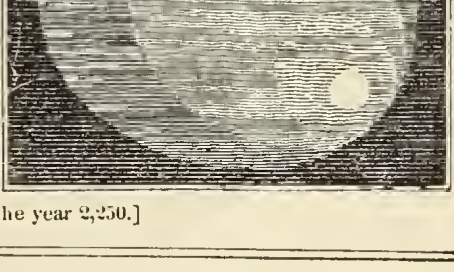
689. *Are they subject to the Law of Gravitation?*

They are; but are so light as to have no sensible effect upon the planets.

[1. While Jupiter and Saturn often *retard* and delay comets for months in their periodic revolutions, comets have not power in turn to *hasten* the time of the planets for a single hour. The comet of 1770 got entangled, by attraction, among the Moons of Jupiter, on its way to the Sun, and remained near them for *four months;* yet it did not sensibly affect Jupiter or his Moons. This shows conclusively that the relative masses of the comets and planets are almost infinitely disproportionate.

2. The fact that they revolve about the Sun, is a sufficient proof of their being subject to the great law of gravitation.]

ENCKE'S COMET.



690. *What is known of the* PERIODIC TIMES *of Comets?*

Only four or five have been ascertained; and these vary from $3\frac{1}{3}$ to 570 years.

[The following periodic revolutions have been fully determined:

Encke's Comet	$3\frac{1}{3}$	years.
Biela's "	$6\frac{3}{4}$	"
Halley's "	76	"
Comet of 1680	570	"

The next return of this last will be in the year 2,250.]

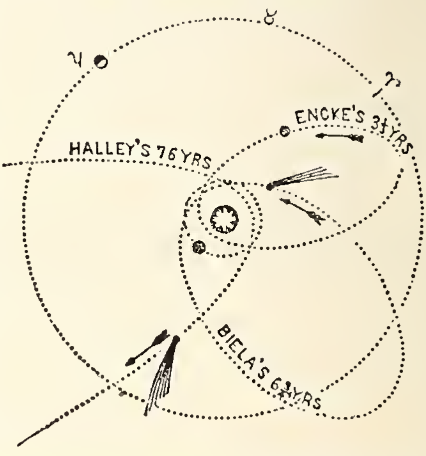
691. *Are all Comets supposed to revolve continually around the Sun?*

Professor Nichol and Sir John Herschel are of opinion that the greater number visit our system but once, and then fly off in nearly straight lines, till they pass the center of attraction between the Solar System and the Fixed Stars, and go to revolve around other Suns in the far-distant heavens.

692. *What can we say of the* DISTANCE *to which many Comets go?*

In some cases it must be immense, from the time they are gone, and the rapidity of their motions.

ORBITS OF SEVERAL COMETS.



[1. The orbit of Encke's comet is wholly within the orbit of Jupiter, while that of Biela's extends but a short distance beyond it. The aphelion distance of Halley's comet is 3,400 millions of miles, or 550 millions of miles beyond the orbit of Neptune. But these are all comets of short periods.

2. Though the distance to which some comets go, to be so long absent, must be very great, still their bounds are set by the great law of attraction; for were they to pass the point "where gravitation turns the other way," they would never return. But most, if not all, *do* return, after their "long travel of a thousand years." What a sublime conception this affords us of the almost infinite space between the Solar System and the Fixed Stars!

3. The student will find the entire orbit of a comet represented in the second cut on page 30. The aphelion point is represented as only about half way to the Fixed Stars.]

693. *How were Comets regarded by the ancients?*

As harbingers of famine, pestilence, war, and other dire calamities.

[The comet of 1811 was regarded by the ignorant as the precursor of the war that was declared in the following spring. In one or two instances comets have excited serious apprehension that the day of judgment was at hand; and that they were the appointed messengers of Divine wrath, hasting apace to burn up the world. This was the case with a large comet that appeared in 1456.]

694. *What other fears have been entertained with regard to Comets?*

That they might come into collision with our globe, and either dash it to pieces, or burn every thing from its surface.

695. *Is there really any danger of collision?*

None at all; the thing is next to impossible.

[1. It has been determined, upon mathematical principles, and after the most extended and laborious calculation, that of 281,000,000 of chances, there is only *one* unfavorable, or that can produce a collision between the two bodies.

2. When we consider the order and harmony that prevail throughout the planetary system, and remember that the same infinitely wise and powerful Being that guides the planets in their courses, marks also the pathway of every comet, it is not easy to admit that they are plunging through the system at random, and are liable to come in collision with the planets. It would argue a want of *design* and *perfection* in the mechanism of the heavens, which would be a reflection upon the Divine Architect.]

696. *Would it be destructive if a collision were actually to take place?*

Probably not. Comets are generally too light even to penetrate our atmosphere to the Earth's surface.

[1. The air is to us what the waters are to fish. Some fish swim around in the deep, while others, like lobsters and oysters, keep on the bottom. So birds wing tho air, while men and beasts are the "lobsters" that crawl around on the bottom. Now there is no more probability that a comet would pass through the atmosphere, and injure us upon the Earth, than there is that a handful of *fog* or vapor thrown down upon the surface of the ocean, would pass through and kill the shell-fish at the bottom.

2. Professor Olmsted remarks that, in the event of a collision, not a particle of the comet would reach the Earth—that the portions encountered by her would bo arrested by the atmosphere, and probably inflamed; and that they would perhaps exhibit, on a more magnificent scale than was ever before observed, the phenomena of shooting stars, or meteoric showers.]

LESSON XXXIII.

OF THE SUN.

697. *How is the Sun distinguished?*

As the great center of the Solar System, the fountain of light and heat. (See also 131.)

698. *What names did the ancients give to the Sun?*

The Romans called him *Sol*, and the Greeks *Helios*. (See Notes to 126 and 305.)

699. *What did they suppose him to be?*

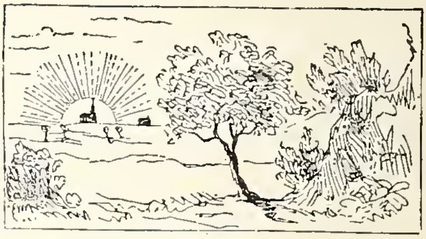
A vast globe of fire.

[It is by no means strange that this opinion should obtain among the ancients with respect to the Sun. It has even been held by some modern astronomers, among whom is the celebrated and profound La Place. This opinion, however, is now almost universally rejected. The heat produced by the light of the Sun is found not to be transmitted from him, but to be produced by the *contact* of the rays with other substances; and greatly modified by the relative density of the atmosphere.]

700. *What is his* MAGNITUDE?

He is 886,000 miles in diameter.

SUN RISING IN THE DISTANCE BEHIND A CHURCH.



[1. The vast magnitude of the Sun may be inferred from the fact that when rising or setting he often *appears* larger than the largest building, or the tops of the largest trees. Now if the angle filled by him at the distance of two miles is over 100 feet across, what must it be at the distance of 95 millions of miles?

2. Were a railroad passed through the Sun's center, and should a train of cars start from one side, and proceed on at the rate of 30 miles an hour, it would require 3¼ years to cross over his diameter. To traverse his vast circumference, at the same rate of speed, would require nearly 11 years.

3. The Earth's diameter is 7,912 miles; and yet it would take 112 such globes, if laid side by side, to reach across the diameter of the Sun: $886{,}000 \div 7{,}912 = 112$, nearly.]

701. *What is his Magnitude or mass as compared with our globe?*

He is equal to 1,400,000 such worlds.

[1. For comparative magnitudes of the Sun and planets, see cut, page 43.

2. The student will bear in mind that the magnitudes of spherical bodies are not in proportion to the *diameters*, but to the *cubes* of their diameter. See Note after 187.]

702. *How does the Sun compare, as to size, with the rest of the system?*

He is 500 times larger than all the other bodies of the system put together.

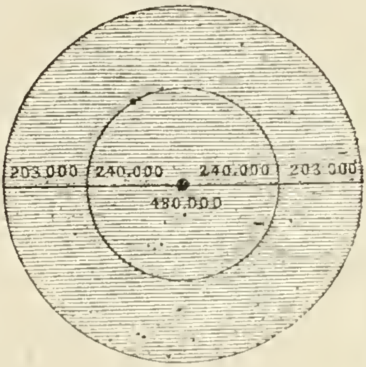
[This estimate includes all the planets, primary and secondary, but has no reference to comets.]

703. *How does he compare with the size of the Moon's orbit?*

If his center occupied the position of the Earth, he would fill the whole orbit of the Moon, and extend more than 200,000 miles beyond it in every direction.

[The mean distance of the Moon from the Earth's center is 240,000 miles; consequently the diameter of her orbit, which is twice the radius, is 480,000. Subtract this from 886,000, the Sun's diameter, and we have 406,000 miles left, or 203,000 miles on each side, beyond the Moon's orbit.]

THE SUN, AND THE MOON'S ORBIT.



704. *How does the Sun appear through a Telescope?*

Like a vast globe of fire, with dark *spots* here and there upon its surface.

705. *What is the* NUMBER *of these Spots?*

It varies at different times from two or three to fifty.

TELESCOPIC VIEW OF THE SUN

[1. Much depends, of course, upon the power of the instrument through which he is viewed; as some telescopes will reveal much more than others.

2. For several days, during the latter part of September, 1846, the author could count sixteen of these spots which were distinctly visible, and most of them well defined; but on the 7th of October following, only six small spots were visible, though the same telescope was used, and circumstances were equally favorable.

3. The Sun is a difficult object to view through a telescope, even when the eye is protected in the best manner by colored glasses. In some cases (as in one related to the author by Professor Caswell, of Brown University) the heat becomes so great as to spoil the eye-pieces of the instrument, and sometimes the eye of the observer is irreparably injured.]

706. *Do these Spots appear stationary, or in motion?*

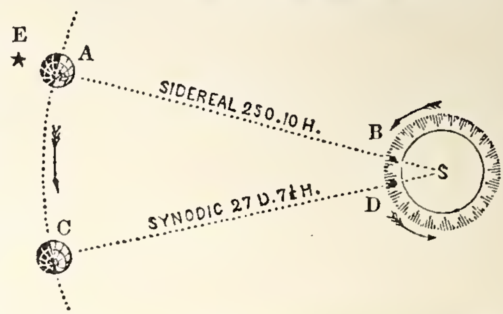
They appear to pass over the Sun from left to right in about $13\frac{1}{2}$ days.

707. *What has been inferred from this fact?*

That the Sun revolves on his axis, from west to east, or in the direction of all the planets, every $25\frac{1}{2}$ days (25 d. 10 h.)

[1. This is the time of his *sidereal* or *true revolution.* His *apparent* or *synodic* revolution requires 27 days, $7\frac{1}{2}$ hours; but this is as much more than a complete revolution upon his axis, as the Earth has advanced in her orbit in $25\frac{1}{2}$ days. Let S represent

SIDEREAL AND SYNODIC REVOLUTIONS OF THE SUN.



the Sun, and A the Earth in her orbit. When she is at A, a spot is seen upon the disk of the Sun at B. The Sun revolves in the direction of the arrows, and in 25 days, 10 hours, the spot comes round to B again, or opposite the star E. This is a *sidereal* revolution.

2. During these 25 days, 10 hours, the Earth has passed on in her orbit some 25°, or nearly to C, which will require nearly two days for the spot at B to get directly toward the Earth, as shown at D. This last is a *synodic* revolution. It consists of one complete revolution of the Sun upon his axis, and about 27° over.]

708. *Where are these Spots situated?*

They are usually on each side of the Sun's equator, and within a zone of 60°.

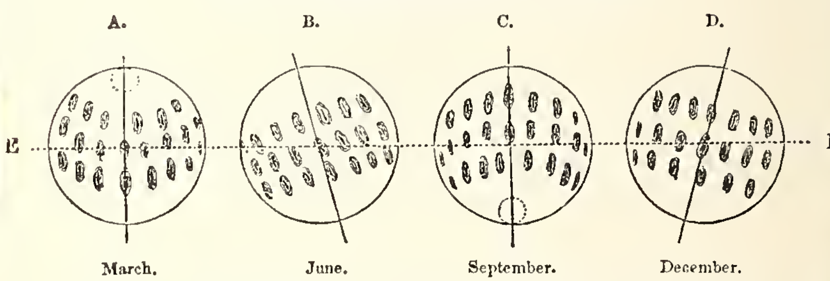
709. *How is the Sun's Axis situated with respect to the Ecliptic?*

It is inclined toward it 7° 20′.

710. *How was this inclination ascertained?*

By observing changes in the *direction* of the solar spots, at different seasons of the year.

VARIOUS DIRECTIONS OF THE SOLAR SPOTS.



[1. Let E F represent the plane of the ecliptic. In March the spots describe a curve, which is convex to the south, as shown at A. In June they cross the Sun's disk in nearly straight lines, but incline upward. In September they curve again, though in the opposite direction; and in December pass over in straight lines, inclining *downward*.

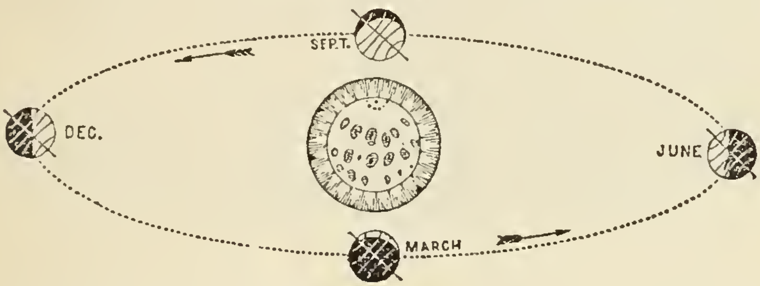
2. The figures B and D show the inclination of the Sun's axis.]

711. *How does this prove that the Sun's Axis is inclined?*

If the Sun's axis were perpendicular to the ecliptic, the spots would revolve in circles *parallel* to the ecliptic, and apparently in straight lines; whereas the inclination of his axis would give the spots precisely these motions during the year.

[This subject will be fully understood by consulting the following figure, in connection with the preceding:

SOLAR SPOTS OBSERVED FROM DIFFERENT POINTS.



1. If the Sun's axis were at right angles with the ecliptic, his equator and the spots upon his disk must revolve parallel to the ecliptic, and would appear to cross his disk in straight lines, from all parts of the Earth's orbit, or throughout the year.

2. In *March*, however, the spots move in curve lines, as represented in the cut, showing that the North Pole of the Sun inclines toward us.

3. In *June* we have a *side view* of the Sun's axis, and the spots seem to pass *upward* in straight lines, as represented at B on the opposite page.

4. In *September* the *South Pole* of the Sun inclines toward us, and the spots again move in curve lines, the reverse of what they were six months before.

5. In *December* we have another side view of the axis, and the spots cross in straight lines, inclining *downward*, as shown in the opposite figure at D.]

712. *What is the Size of the Solar Spots?*

They are of various sizes and forms, some having been estimated at 50,000 miles across.

713. *What is their general appearance?*

They are darkest in the middle, and are shaded off at the edges by a sort of penumbra.

714. *Do they appear of the same size throughout their whole course?*

They appear narrow when first seen on the Sun's eastern limb; expand gradually till they reach the center; and then contract till they pass off on the west.

715. *What is the* CAUSE *of this apparent expansion and contraction?*

It is because the spots are on the surface of a globe, and are seen partly *edgewise*, except when near the Sun's center.

716. *Is their* RATE OF MOTION *across the Sun uniform?*

It is not; but is *accelerated* from the eastern limb to the center, and *retarded* from the center to the western edge.

717. *What are these Spots supposed to be?*

They are generally thought to be openings through the luminous atmosphere of the Sun.

[Some have thought them to be the tops of mountains, laid bare by tides, or other fluctuations of the solar atmosphere.]

718. *What is the prevailing opinion in regard to the* NATURE *of the Sun?*

That his body is *opake;* and that his light proceeds from a luminous atmosphere that surrounds him.

THE ZODIACAL LIGHT.

719. *What is the* ZODIACAL* LIGHT?

It is a faint nebulous light, resembling the tail of a comet, sometimes seen in the neighborhood of the Sun.

720. *At what time may it be seen?*

Just after sundown or before sunrise in March, April, October, and November.

721. *What is its* APPEARANCE?

It is quite faint, hardly distinguishable from ordinary twilight.

722. *What is its* FORM *and* POSITION?

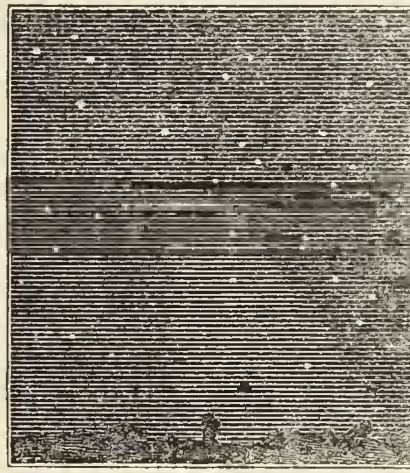
It has the form of a *pyramid*, with its base toward

---

* ZO-DI'-AC-AL.

the Sun, and inclines a little toward the horizon.

ZODIACAL LIGHT.



723. *How far does it extend from the Sun?*

From forty to ninety degrees.

724. *What is its* WIDTH *at the base?*

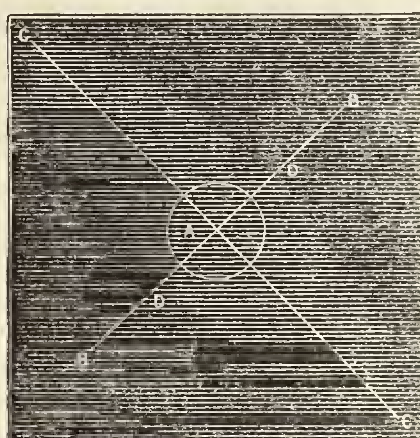
It varies from eight to thirty degrees.

725. *How is this substance situated with respect to the Sun's equator?*

Its major axis is at right angles with the axis of the Sun.

[Let A represent the Sun, B B his axis, then C C will represent the extent, and D D the thickness of this curious appendage to the Sun.]

FORM, EXTENT, ETC., OF THE ZODIACAL LIGHT.



726. *What is this Light supposed to be?*

Some have thought it an extension of the Sun's *atmosphere*, while others have regarded it as *nebulous vapor*, of the nature of comets.

727. *Is it thought to be at rest, or in revolution?*

It is believed to revolve with the Sun on his axis, and to be flattened out as we see it, by that revolution.

[See the effect of the revolution of yielding bodies upon their figure illustrated, page 61. The form is supposed to be that of a *lens*, of which the above is an edgewise view.]

728. *What other motion has the Sun besides that on its Axis?*

A slight periodical revolution around the common center of gravity of the Solar System.

[This motion resembles that of the Earth, illustrated on page 133, to which the student is referred. The Sun never deviates from his apparent fixed position to the amount of more than twice his diameter.]

729. *Has he still another motion?*

He is found to be revolving, with all his retinue of planets and comets, in a *vast orbit*, around some distant and unknown center.

[1. This supposed orbit is represented in the second cut on page 30, to which the student will do well to turn.

2. Professor Mädler, of Dorpat, in Russia, has recently announced as a discovery that the star *Alcyone*, one of the seven stars, is the center around which the Sun and Solar System are revolving.

3. What a stupendous idea! Secondaries revolving around primaries; primaries around the Sun; and the Sun around some other center; and so on, till we come to the center of all other centers; or, as Dr. Dick remarks, "to the THRONE OF GOD!"]

730. *What is the estimated* VELOCITY *of the Sun and Solar System?*

About 28,000 miles per hour, or 8 miles per second.

731. *What is the supposed Period of Revolution?*

About 18,200,000 years.

[If this be correct, he has only passed over one 3,000th part of his orbit, or about seven degrees since the creation of the world—an arc so small compared with the whole, as to be hardly distinguishable from a straight line.]

LESSON XXXIV.

GENERAL REMARKS UPON THE SOLAR SYSTEM.

732. *How did the Solar System originate?*

The Scriptures say that "in the beginning God *created* the heaven and the earth" (Gen. i. 1).

733. *Describe the* NEBULAR THEORY *of Creation.*

It teaches that the elements or matter, of which the system is composed, was originally a vast cloud of vapor or mist, which has been condensed and formed into Sun and planets, during a vast period of time, by the simple law of gravitation.

734. *Is this theory* CORRECT, *or even* PROBABLE ?

It is not.

735. *What objections can be urged against it?*

1. It would make the creation, mentioned by Moses, a mere *organization* or *arrangement* of pre-existing matter; whereas the Bible says that " the worlds were framed by the *word of God*, so that things which are seen were *not* made of *things which do appear*."—Heb. xi. 3.

2. If it allows that God created the *materials* of the system at all, it throws the period of their creation back indefinitely into eternity, and substitutes gravitation for the direct agency of the Almighty.

736. *What led to the discovery of the first Asteroid?*

The suspicion that there was a large planet in the space between the orbits of Mars and Jupiter.

737. *What singular opinion has been entertained in regard to their* ORIGIN ?

Doctor Olbers, of Bremen, Germany, was of opinion that they were originally one large planet, that had been broken into fragments by *explosion*, or by coming in *collision* with some other body.

738. *What says Dr. Herschel of this theory?*

He says it may serve as a specimen of the *dreams* in which astronomers, like other speculators, occasionally and harmlessly indulge.

739. *Why is this theory improbable?*

Because such an explosion or collision would be at variance with the *harmony* and *order* that every where prevail throughout the planetary regions.

740. *Is it probable that the planets are inhabited by rational beings?*

It is.

741. *Have we any direct evidence of this fact?*

We have not: no inhabitants have ever been *seen*, *heard*, or *heard from*, upon any of the planets.

742. *Is this any proof that they do not exist there?*

It is not. We must not conclude that a newly discovered island is uninhabited, because it is so far distant when first seen that we cannot *see* or *hear* the people.

743. *Why is it believed that the planets are inhabited?*

Because they are globes like our Earth; and have *atmospheres*, *seasons*, *days and nights*, *satellites*, &c., which would be unnecessary if they were uninhabited.

[To create twenty primary planets, and have only one small one inhabited, would be like a father's building twenty houses, all after one model, but of different colors and dimensions, and after having furnished them all with *ventilators*, *mirrors*, *lamps*, &c., to put an only son into one of the smallest, and leave the remaining nineteen unoccupied.]

744. *Do not the extremes of Cold and Heat upon the several planets forbid their being inhabited?*

By no means. The Creator adapts every creature to the place where he designs it to dwell.

[Fish have *cold blood*; and some animals may be frozen stiff, and when thawed out will come to life. The lion and polar bear are each adapted to their respective abodes, and so with every thing in nature. And why may not the same law extend to the planets? Cannot He, who adapted the three Hebrews to the fiery furnace (Dan. iii. 27), adapt beings to the temperature of Mercury? Upon the same principle beings may exist even upon Neptune, to whom a milder climate would be uncomfortable.]

What part of the book have you now gone over?

Parts *First* and *Second*, including Preliminary Observations and Definitions; and what relates to the SOLAR SYSTEM.

What yet remains to be examined?

PART THIRD, which relates to the SIDEREAL HEAVENS.

PART III.

THE SIDEREAL HEAVENS.

LESSON XXXV.

THE FIXED STARS—THEIR NUMBER, DISTANCES, MAGNITUDES, ETC.

745. *What is meant by the* Sidereal Heavens (127)?

746. *Why are some Stars called* Fixed Stars?

Because they occupy the same positions with respect to each other from age to age, while the planets are seen to be in motion.

747. *In what other respect do the Fixed Stars differ from the planets?*

They are *self-luminous*, and seem to *twinkle* or *scintillate*, while the planets appear tranquil and serene.

748. *How may a Fixed Star be distinguished from a planet by the aid of a Telescope?*

The planets exhibit a round, mild-looking disk, while the Fixed Stars appear only as a point of brilliant light.

749. *How are the Fixed Stars situated with respect to the Solar System?*

They are inconceivably distant, and surround our system in every direction.

[Were it not for the Sun, we should see the stars in the day-time as well as in the night. See 557.]

750. *What is the estimated* distance *of the Fixed Stars?*

The *nearest* are supposed to be 20,000,000,000 (*twenty billions*) of miles from the Sun, or more than 7,000 times as far off as Neptune.

[1. For light to pass over this space, at the rate of 200,000 miles per second, would require upward of three years.

2. Were the Earth's orbit one vast circle of light, it would not appear larger than a lady's finger-ring from the nearest Fixed Star.]

751. *How would our Sun appear from such a distance?*

Only like a bright star.

752. *What are the Fixed Stars supposed to be?*

Distant *Suns*, and centers of other planetary systems.

753. *How, then, should we regard our own Sun?*

As one of thousands of Suns, but appearing vastly more brilliant than the rest, solely because of our nearness to him.

754. *How do the Stars appear in the heavens?*

They seem to be equally distant from us, and scattered at random over the concave firmament.

755. *What can you say of their apparent* SIZE?

They vary from the large and bright star to the smallest that the eye can discover.

756. *What is the cause of this variation?*

It is due, in a great measure, to the variation in their *distances*.

757. *How are the Stars classified?*

They are first arranged in groups, or patches, called *constellations*.

758. *How are the Constellations distinguished?*

They are named after some animal or object which the ancients imagined them to resemble.

759. *Into how many constellations are the heavens divided?*

Ninety-three.

760. *How are they situated?*

Twelve in the Zodiac, 35 north, and 46 south of it.

761. *Can you name one of the most conspicuous in each of these divisions?*

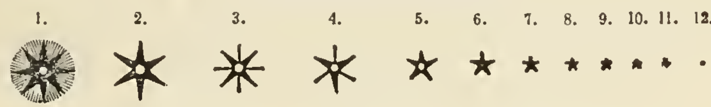
The *Great Bear* in the north; *Taurus* in the Zodiac; and *Orion* just south of the Zodiac.

[If the student will look up these three in the heavens, it will form a good beginning, and will be of great service when he comes to take up the study anew, with a more advanced text-book.]

762. *What is the* SECOND *step in classifying the Stars?*

They are divided into twelve classes, according to their *apparent magnitudes.*

STARS OF DIFFERENT MAGNITUDES.



763. *How many of these can be seen by the naked eye?*

Only the first six classes. The remaining six are seen only by the aid of *telescopes*, and are called *Telescopic Stars.*

764. *What is the* THIRD *step in classifying the Stars?*

To classify the stars *in each constellation* by the use of the Greek alphabet, calling the largest *alpha* (α), the next largest *beta* (β), &c. When the Greek alphabet is exhausted, the Roman is taken up; and when this fails, recourse is had to figures.

765. *Is there any other method by which particular Stars are designated?*

Many have specific *names*, as *Arcturus*, *Sirius*, *Aldebaran*, &c.

766. *What is the estimated* NUMBER *of the Fixed Stars?*

No finite mind can number them, but estimates have been made amounting to near 400 millions.

[The Psalmist asserts the infinite knowledge of God, by saying that "He telleth the number of the stars, and calleth them all by their names."—Psalm cxlvii. 4.]

767. *In what proportion do the several Magnitudes occur?*

There are but few of the first magnitude, and the number increases rapidly as the magnitudes diminish.

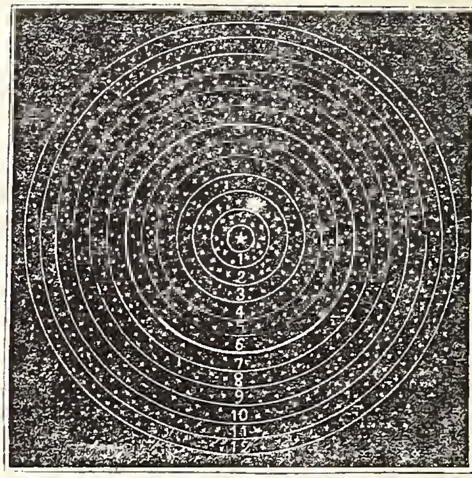
[The number of stars down to the twelfth magnitude, has been estimated as follows:

Visible to the naked eye,	1st magnitude........	18	Visible only through telescopes,	7th magnitude.	26,000
	2d "	52		8th " .	170,000
	3d "	177		9th " .	1,100,000
	4th "	376		10th " .	7,000,000
	5th "	1,000		11th " .	46,000,000
	6th "	4,000		12th " .	300,000,000
		5,623		Total number..	354,301,623]

768. *Why are there so many more of the small Stars than of the large ones?*

It is because we are in the midst of a great cluster, with but few stars near us, the number increasing as the circumference of our view is enlarged. See second cut, page 30.

NUMBER OF STARS OF EACH MAGNITUDE.



[1. We have here a representation of a great cluster of stars. Let the central star represent the Sun (a star only among the rest), with the Solar System revolving between him and the first circle. The 18 stars in space 1st will appear to be of the first magnitude, on account of their *nearness*, and they are thus few because they embrace but a small part of the entire cluster. The stars of space 2 will appear smaller, being more distant, but as it embraces more space, they will be more numerous. Thus as we advance from one circle to another, the apparent magnitude constantly diminishes, but the *number* constantly increases. The large white circle marks the limit of our natural vision.

2. Even this cut fails to present fully to the eye the cause of the rapid increase in numbers; for we can only show the surface of a *cut section* of our firmament of stars, which exhibits the increase in a plane only; whereas our Sun seems to be imbedded in the midst of a magnificent cluster, the stars of which we view around us *in every direction.*]

769. *Is any thing known of the actual* MAGNITUDE *of the Stars?*

Nothing very definite, though many of them are estimated to be much larger than our Sun.

[The diameter of some of the Fixed Stars has been estimated at 200,000,000 miles, or more than 200 times the diameter of the Sun.]

LESSON XXXVI.

OF DOUBLE, VARIABLE, AND TEMPORARY STARS.

770. *What are Double Stars?*

Such as appear single to the naked eye, but when examined by the telescope are found to be double.

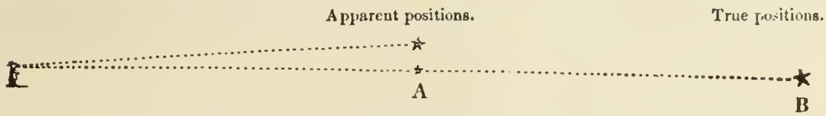
[1. The North Pole Star appears like a small single star to the naked eye, but with a telescope is found to consist of two.

2. In many cases, what appears to be a single star is found to consist of from three to six, and even more.]

771. *Is it likely that all Stars that appear double are actually near each other?*

It is not. Probably many appear near each other simply because they are near the same line of vision.

WHY STARS MAY APPEAR DOUBLE.



[Here the observer on the left sees a large and small star at A, apparently near together; the lower star being much the smallest. But instead of their being situated as they appear to be, with respect to each other, the true position of the smaller star may be at B instead of A; and the difference in their apparent magnitudes may be wholly owing to the greater distance of the lower star.]

772. *In what sense are Stars said to be double when one is far beyond the other?*

They are said to be *optically* double.

773. *How many Double Stars are to be met with in the Heavens?*

It is supposed there are not less than *six thousand.*

774. *What suspicion did the great number of Double Stars awaken in the minds of astronomers?*

That such stars were specially connected by gravitation.

775. *What surprising fact has been ascertained in regard to some of the Double Stars?*

That they are actually revolving one around another, or both around the center of gravity between them.

776. *How do we distinguish Double Stars that are thus connected?*

As being *physically* double.

777. *What are these Systems called?*

Binary Systems.

[These, it must be remembered, consist of one or more *Suns* revolving as described, but so distant as to appear only as stars.]

778. *Are there many of these Binary Systems?*

Sir William Herschel noticed about fifty instances of changes in the relative position of double stars, and the revolution of some sixteen he considered certain.

779. *In what time do they revolve?*

From forty to twelve hundred years.

780. *What are* VARIABLE STARS?

Such as undergo a regular periodical increase and diminution of light.

781. *What are the* CAUSES *of these variations?*

They are not known. It is thought they may be less luminous on one side than the other; and, by turning on their axes, may vary in brilliancy on that account; or that planets revolving near them may cut off a portion of their light at regular intervals.

782. *What are* TEMPORARY *Stars?*

Such as have disappeared from the heavens, and such as shine out suddenly, in a place previously void, as though just created.

[Some writers classify these under the head of *New* and *Lost* Stars.]

783. *Are these sudden appearances and disappearances frequent?*

Ten new stars have appeared, and *thirteen* old ones seem to have perished, during the last hundred years.

784. *How have some Christian writers regarded these sudden disappearances of Stars?*

As the terminations of probationary periods, like the conflagration that is to take place upon our own globe at the end of time. (See 2 Peter iii. 7, 10.)

LESSON XXXVII.

CLUSTERS OF STARS AND NEBULÆ.

785. *What are Clusters of Stars?*

They are patches in the heavens where the stars are unusually thick or near together.

786. *Can you name any specimens of Clusters?*

The *Seven Stars*, or *Pleiades*, and the *Hyades* just east of them.

787. *Are these Clusters numerous?*

With a telescope many hundreds may be seen.

A CLUSTER OF STARS.

788. *How do they appear through a Telescope?*

They are found to consist, in many instances, of thousands of stars, as if constituting a separate universe by themselves.

789. *What are* NEBULÆ?*

Clusters of stars so remote as to appear through common telescopes like a faint haze of light.

790. *How are the Nebulæ distinguished?*

Into *Resolvable*, *Irresolvable*, *Planetary*, *Stellar*, and *Annular*.

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* NEB'-U-LA, singular; *Neb-u-læ*, plural.

791. *What are* Resolvable *Nebulæ?*

Clusters, the light of whose individual stars appears blended through ordinary instruments, but which can be resolved into distinct stars by telescopes of higher power.

792. *What are* Irresolvable *Nebulæ?*

Faint patches of light, formerly supposed to be vast fields of unorganized matter, in a high state of rarefaction.

793. *What has Lord Ross announced in regard to these bodies?*

That nearly 200 nebulæ, hitherto considered irresolvable, were easily separated into stars by his magnificent telescope.

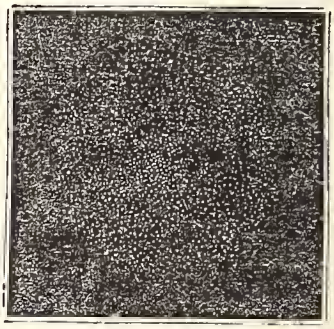
794. *What does this seem to prove as to this class of Nebulæ?*

That they could all be resolved into distinct stars, if we had telescopes of sufficient power.

795. *What are* Planetary *Nebulæ?*

Clusters so nearly round as to resemble planets through ordinary telescopes.

PLANETARY NEBULÆ.



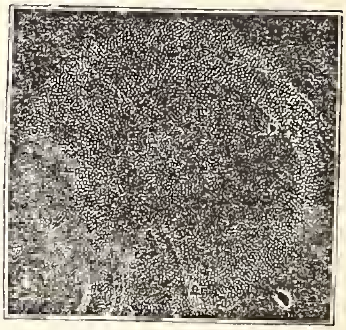
796. *What are* Stellar *Nebulæ?*

Such as seem to have a bright star at or near their center.

797. *Where are these Stars probably situated?*

In the *direction* of the nebulæ, but between them and the observer.

ANNULAR NEBULÆ.



798. *What are* Annular *Nebulæ?*

Clusters that have the appearance of a *ring*, the stars being much thicker around the edge than in the center.

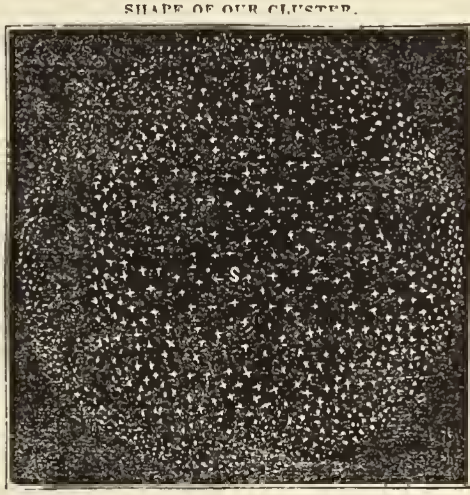
799. *What is the* GALAXY *or* MILKY WAY *of our own Firmament?*

It is a zone of light surrounding the heavens, which is found by the telescope to consist of countless myriads of stars.

800. *How do astronomers account for the vast number of small Stars in this Belt?*

They suppose our cluster to be in the form of a *lens* or oblate spheroid very much flattened; and that the Milky Way is an *edgewise view* from a position near the center.

SHAPE OF OUR CLUSTER.



[1. The annexed cut is a representation of the great stellar cluster, immediately surrounding the Solar System. It may be regarded as a side view of the cluster. Let the star near S represent the Sun, and imagine the most distant planets and comets to revolve between S and the star. Then if a person upon the Earth near the star were to look out of the cluster toward the eye of the reader, or the back of the book, the stars would appear large and scattering; but if he looked off in the direction of the edge of the cut, they would appear much more numerous, constituting a belt of small stars around the heavens.

2. On the left is seen an opening intended to represent a division that is seen extending for some distance in the zone of the Milky Way.

EDGE VIEW.

3. It is supposed that if we could place ourselves at a distance beyond the most remote star in this immense cluster, and take an *edgewise* view of it as a whole, it would appear much as here represented—the division in the line of the Milky Way being again shown on the left.]

801. *Where are the Nebulæ supposed to be situated?*

Entirely beyond the great cluster composing our own immediate firmament.

802. *How do they appear through the most powerful Telescopes?*

They are found to be vast collections of glowing stars.

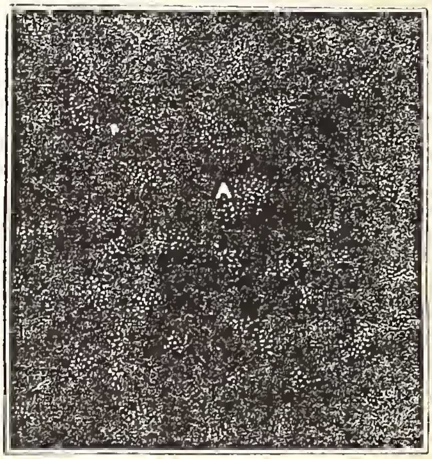
803. *What are they supposed to be?*

Clusters like that in the midst of which the Solar System is found, but so remote as to appear like faint patches of light.

804. *What, then, is the supposed structure of the Universe?*

It is supposed to consist of vast distinct clusters, at immense distances from each other, and composed of stars, each of which is a *Sun*, surrounded by his own retinue of revolving worlds.

SUPPOSED STRUCTURE OF THE UNIVERSE.



[Let A represent our own cluster, with the Sun and Solar System somewhere in its bosom. Then the nearest groups would appear as *clusters*, the next nearest like *resolvable* nebulæ, and the more remote like *irresolvable* nebulæ. But to an eye that could take in a wide field of immensity the several clusters would appear isolated, as represented in the cut. At least these are the conclusions to which astronomers arrive by observations upon the nebulæ in the far-distant heavens.]

805. *How would things appear if we were to pass out of our own cluster, and to go to one of those Nebula?*

As we passed star after star, on our way to the borders of our cluster, they would swell to the magnitude of *Suns*, and again diminish to stars; while our own Sun would gradually dwindle to a star, and finally disappear. As we left our cluster, it also would contract, while the distant nebulæ expanded as we approached and entered them, till at length we should find ourselves surrounded by a new firmament of constellations, and our own cluster would appear only as a distant nebula.

LESSON XXXVIII.

OF THE ATMOSPHERE, WINDS, CLOUDS, STORMS, ETC.

806. *What is the* Atmosphere ?

It is the air we breathe, an elastic gas which surrounds the globe on every side.

807. *To what hight does it extend above the Earth?*

Its precise hight is not known, but it is supposed to extend from 40 to 60 miles.

808. *What keeps it so closely wrapped around the Globe?*

The same power that keeps the waters in their place; namely, gravitation.

809. *Why does not the Air get swept off from the Globe in its rapid motion around the Sun?*

Because there is no substance to sweep it off, the region through which the Earth passes being entirely empty.

810. *Does the Air, then, revolve with the Earth?*

It does, both around the Sun and the Earth's axis.

811. *Is the Density of the Air the same at all elevations?*

It is not; but grows more rare as we ascend from the Earth's surface.

812. *What is* Wind?

It is air put in motion.

813. *What is the Velocity of the Air in a gentle, pleasant Wind?*

From four to five miles an hour.

814. *What of Brisk or High Winds?*

From fifteen to fifty miles an hour.

815. *What is the Velocity of the Air in a* Storm?

From fifty to sixty miles an hour.

816. *What is the Velocity in a* Hurricane?

From eighty to one hundred miles an hour.

817. *What is the cause of Winds, Storms, and Hurricanes?*

The influence of heat, causing bodies of air to rise, and other air to rush in to supply its place.

[Whenever air is heated it expands, and becomes lighter than cold air, so that the tendency is to ascend. It is this which causes flame and smoke to ascend. On this account, also, if a large fire take place when the air appears perfectly still, the wind will seem to blow in every direction toward it.]

818. *What are* Clouds?

A collection of misty vapors suspended in the air.

819. *How high are the Clouds?*

They range from two miles to half a mile, according to their density and weight.

820. *Of what benefit are Clouds to us?*

They often screen us from the oppressive heat of the Sun, and convey water from the rivers and oceans, and pour it down in showers upon the Earth.

821. *What is* Rain?

Water condensed, or collected into drops by attraction, and falling from the clouds.

822. *What is* Hail?

Drops of rain frozen on their way from the clouds to the Earth.

823. *What is* Snow?

Particles of clouds frozen before being condensed into drops, and falling to the Earth.

824. *What is* Lightning?

The passage of a fluid called *electricity*, from one cloud to another, or from the clouds to the Earth.

825. *What is* Thunder?

A sudden shock given to the atmosphere by the passage of electricity through it.

826. *Why do we generally see the Lightning before we hear the Thunder?*

Because the velocity of light is much greater than that of sound.

827. *Is there any danger after the flash of Lightning is past, though we have not heard the Thunder?*

There is not. It is the lightning that does the harm, and not the thunder.

828. *What is the* AURORA BOREALIS, *or* NORTHERN LIGHTS?

A reddish, unsteady light, that is sometimes seen in the North.

829. *Is the cause of this Light known?*

It is not; but it is generally supposed to be produced by electricity.

OCCULTATION OF A STAR.

830. *What is meant by the* OCCULTATION *of a Star?*

It is when the Moon passes between the Earth and a star, and for a time hides it from view.

[The cut represents the New Moon just about to occult the star on the left.]

831. *What are* "SHOOTING STARS?"

Meteors that shoot from the sky downward toward the Earth, like stars falling from their spheres.

832. *How are they generally seen?*

One at a time, and only in the night.

833. *Do they ever fall in great numbers?*

They do. From two o'clock in the morning till daylight, on the 13th of November, 1833, the whole heavens were filled with fiery particles, and streaks of light darting downward from the sky.

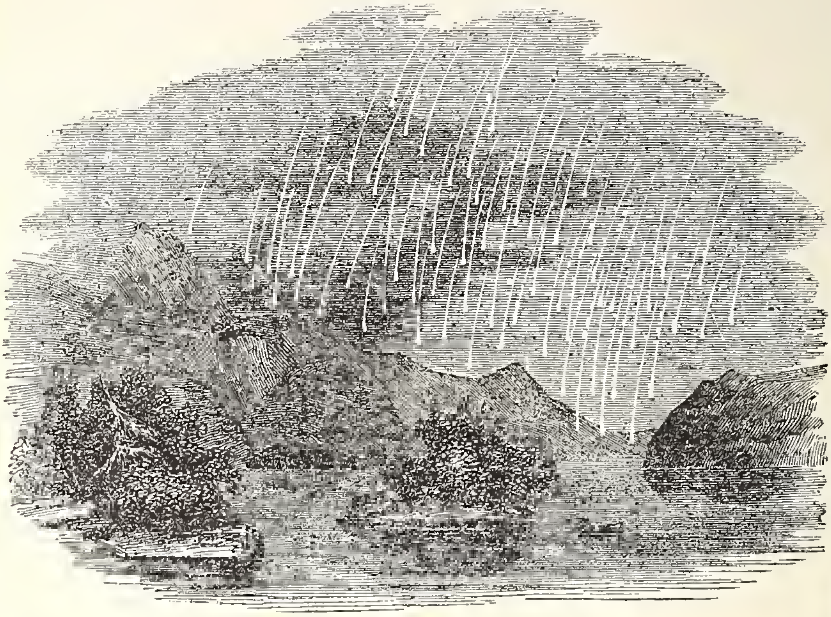
834. *Is it known what these Meteors are?*

It is not.

835. *Where are they supposed to come from?*

From the regions beyond our atmosphere.

A METEORIC SHOWER.



836. *How are they supposed to be set on fire?*

By friction, in passing with great velocity through the atmosphere.

A LARGE METEOR.

837. *Do they always appear small, as represented in the above cut?*

They do not. Meteors of great size have been known to traverse the atmosphere, and to explode with a loud report.

838. *Is any substance ever found belonging to Meteors?*

What are called *Meteoric Stones*, and masses of iron, have fallen from the sky at various periods, and on almost every part of the globe.