EMMONS' ASTRONOMY.

# ELEMENTARY

# ASTRONOMY:

FOR THE

## USE OF PUBLIC SCHOOLS,

AND PRIVATE FAMILIES.

By Prof. WM. EMMONS, Elba, N.Y.
Late Lecturer on Astronomy, in Cary Collegiate Seminary; Author of a Series of Astronomical Maps.



SECOND REVISED EDITION.

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# PREFACE.

It is due to the public, that a succinct statement be made of the reasons which have induced the author to introduce this new candidate for favor and patronage. Works of great merit and worth, on the Science of Astronomy, abound; but *they do not fully meet the wants of the learner in Elementary Astronomy.* Most of them are mathematically abstruse, and are interspersed with such multitudes of separate diagrams, that the learner becomes confused, and fails to obtain a clear and comprehensive idea of the anatomy and structure of the Solar System.

From a diagram of the earth in one place; of the moon, in another; of the planets, somewhere else; of solar and lunar eclipses, in another; detached portions of the orbits of planets, elsewhere; and comets, &c. &c., in still another place—most young learners obtain as clear and well-defined conceptions of the grand and harmonious structure of the Solar System, as would a boy, of a clock or watch, who had never seen one in all the nice combinations of their parts, by simply seeing detached and intricate portions scattered around him.

Several years since, the author published an Astronomical Chart or Diagram, in which the structure of the Solar System is exhibited at one view. A prominent design of the present work, is to teach and illustrate Astronomy in connection with that Chart.

The author has been induced to undertake the preparation and publication of this work, through the repeated and urgent solicitations of numerous teachers and other scientific gentlemen; and from the flattering reception which his Chart has received from the public.

It is with great pleasure that he acknowledges his indebtedness to numerous authors, from whose works valuable assistance has been obtained in the preparation of this treatise. Among the Astronomical works consulted, may be named, Mattison's, Brockelby's, Robinson's, Mitchell's, and Dick's.

Entire perfection is not claimed for this work; but it is given to the public, in the confidence that its merits will receive that commendation to which it is entitled.

WM. EMMONS.

ELBA, N. Y., April, 1866.

# ASTRONOMY.

## LESSON I.

QUESTION. What is Astronomy?

ANSWER. Astronomy is the science which treats of the heavenly bodies, describes their appearances, determines their magnitudes, and discovers the laws which govern their motions.

Q. What are the Divisions of Astronomy?

A. Astronomy is divided into DESCRIPTIVE, PRACTICAL, PHYSICAL and NAUTICAL.

Q. What is *Descriptive* Astronomy?

A. A description of the appearances and a statement of the facts of the heavenly bodies.

Q. What is *Practical* Astronomy?

A. It consists in computing the magnitudes, determining the distances, recording observations, and making astronomical computations.

Q. What is *Physical* Astronomy?

A. It is the investigation of the laws which govern the celestial motions, and the explanation of the causes which bring about their known results.

Q. What is *Nautical* Astronomy?

A. It is to determine positions on the earth, and subsequently the magnitude of the earth; and hence it is

apparent that Geography and Astronomy are intimately blended together, and the one science cannot be fully understood without the aid of the other.

Q. Is the Science of Astronomy of a recent or of ancient date?

A. None of the sciences can claim a more remote antiquity than that of Astronomy. Job, 1,500 years before Christ, speaks of Arcturus, Orion and Pleiades, and the Chambers of the South; constellations still known by the same names.

Q. Who was the first regular Teacher of Astronomy?

A. Thales, one of the seven wise men of Greece, who flourished 600 years before Christ.

Q. Who first taught that the Sun was placed in the center of the Planetary Orbits?

A. Pythagoras, 500 years before Christ.

Q. What other great Astronomer next embraced and defended the same views?

A. Nicholas Copernicus, a celebrated Prussian astronomer, in A. D. 1510, revived the ancient theory of Pythagoras, which places the sun in the center of the solar system, and sets all the planets in rapid motion around him, as the central and controling force.

Q. What constitutes the Heavenly Bodies?

A. The sun, moons, planets, comets, and stars.

Q. Of what characteristics of the Heavenly Bodies, does Astronomy treat?

A. Their appearance, size, form, arrangement, distance, motions, physical constitution, and their influence on each other.

Q. Are all the Planets, Stars, Comets, &c., of the same size?

A. They are not. The sun and stars are much larger than the planets and moons.

Q. Are they all at the same distance from the Earth?

A. No. The moon is only 240 thousands of miles from the earth, while the sun is 95 millions of miles, and the nearest fixed star is not less than 20 billions of miles distant.

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## LESSON II.

Q. Have all the Heavenly Bodies an inherent splendor, so that they emit light of themselves?

A. No. Some of them are luminous, and some of them are opaque.

Q. What do you mean by a Luminous Body?

A. A body which shines by its own native or inherent splendor—one whose light is in itself; as the sun and fixed stars.

Q. What is an Opaque Body?

A. An opaque body is one that can shine only by reflecting the light of a luminous body; as the planets, moons and comets, shine only by reflecting the light of the sun.

Q. Why do the Moons, Planets and Comets, appear to us as Luminous Bodies, if they are not really such?

A. Because they reflect back to the earth the light of the sun.

Q. What is the form of the Heavenly Bodies?

A. They are nearly round, like a globe or ball; but they more exactly resemble an oblate spheroid.

Q. What constitutes the Solar System?

A. The sun, planets, moons and comets.

Q. Are the Sun, Moons, Planets and Comets, of the Solar System, quiescent bodies, or have they, or any of them, motions of any kind?

A. All the planets, moons and comets, are in rapid and perpetual motion around the sun, according to the laws of central forces and circular motion.

Q. How are the bodies of the Solar System arranged?

A. The sun is situated in the center of the system, with the planets and comets revolving around him at very unequal distances.

Q. What is the direction of the Planets around the Sun?

A. From west to east, or the direction the earth would move to reach the places indicated on the Chart, during the several months of the year.

Q. What is the order in which the Planets are arranged in the Solar System?

A. The sun is in or near the center, and all the planets perform their revolutions around this central luminary, in the following order:

1. The planet Mercury, at the distance from the sun's centre, of - - - 37 millions of miles.
2. Venus, - - - 69 " "
3. The Earth, - - - 95 " "
4. Mars, - - - 145 " "
5. The Asteroids, from 210 to 300 " "
6. Jupiter, - - - 496 " "

7. Saturn, - - - 907 millions of miles.
8. Uranus, - - - 1,824 " "
9. Neptune, - - 2,850 " "

Q. How many Planets are there in the Solar System?

A. Eighty-three is the number known at this time.

Q. Are the Planets all of the same size?

A. No. Some of them are many hundreds of times larger than others.

Q. How many large Planets are there?

A. Eight; viz. Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.

Q. How many small Planets are there, and what are they called?

A. Fifty-seven, called Asteroids.

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## LESSON III.

Q. Where is the place of the Asteroids in the Solar System, where they perform their Revolutions around the Sun?

A. They all revolve between the orbits of Mars and Jupiter—a space of about 349 millions of miles.

Q. How are the Planets Classified or Divided, with reference to their motion?

A. They are divided into two classes, primary and secondary.

Q. What is a Primary Planet?

A. It is one which revolves around the sun only.

Q. What is a Secondary Planet?

A. A secondary planet is one that revolves around a primary planet, and accompanies it in its journey around the sun.

Q. What are the Secondary Planets usually called?

A. They are called satellites or moons.

QUESTIONS ON THE CHART.

Q. How are the Planets shown on the Chart?

A. Around the sun at unequal distances, the planets are shown in their orbits. A number of them are seen attended with a retinue of moons; and Saturn is shown with two broad rings and eight moons.

Q. What is represented on the Chart by the large and small Circles and Circular Figures?

A. The large circles represent the orbits or paths in which the planets move around the sun; and the small circles represent the orbits or paths of the satellites or moons around their primaries; and the circular figures in the large circles or orbits represent the planets; while the small circular figures in the small circles or orbits represent the moons of the planets.

Q. What is shown by this from the Chart?

A. That while the planets are revolving around the sun, the secondaries or moons are moving around their primaries, and keeping up with them in their long journeys around the great central luminary.

Q. What are the Names of the Primary Planets, beginning at the Sun?

A. Mercury, Venus, the Earth, Mars, fifty-seven small planets called Asteroids, Jupiter, Saturn, Uranus, and Neptune.

Q. How many Secondary Planets or Moons are there in the Solar System?

A. It is not positively known that there are more than twenty.

Q. Which of the Planets have Moons?

A. The Earth has one; Jupiter, four; Saturn, eight; Uranus, six; and Neptune, one.

Q. How many Asteroids or Small Planets are shown on the Chart?

A. Four, viz. Ceres, Pallas, Juno, and Vesta.

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## LESSON IV.

Q. Have the Planets any other Revolutions than their journeys around the Sun?

A. Several of them are known to have two revolutions—a rotation on their axis, in connection with their annual revolution around the sun.

Q. What is meant by the Axis of a Planet?

A. The axis of a planet is a straight line, round which it turns.

Q. What is produced by the Rotation of a Planet on its Axis?

A. It has day and night.

Q. What is the Path called, in which a Planet moves around the Sun?

A. It is called its orbit; as the large circles on the Diagram or Chart, represent the paths or orbits in which the planets respectively revolve around the sun.

Q. What is the Earth's Orbit called?

A. It is called the ecliptic.

Q. Why is it called the Ecliptic?

A. Because, eclipses can only happen when the moon is in the plane of its orbit.

Q. What is meant by the Plane of the Earth's Orbit?

A. The smooth and level surface, stretching from one side of the orbit across to the other side.

Q. How many Revolutions have the Secondary Planets or Moons?

A. Three.

Q. What are those Planets called whose orbits lie between the Earth and Sun?

A. They are termed interior planets, because their orbits lie within the earth's orbit.

Q. What are all those Planets called whose orbits are beyond or exterior to the Earth's Orbit?

A. They are called exterior planets, because they perform their revolutions in orbits which lie beyond the earth's orbit. The position of all the planets, interior and exterior, will be readily seen by an inspection of the Chart. It will there be observed that Mercury and Venus are interior planets, since their orbits are within the earth's orbit; and that Mars, the Asteroids, Jupiter, Saturn, Uranus and Neptune, are exterior planets, because their orbits lie outside or beyond the earth's orbit.

## LESSON V.

Q. Has the Earth in all ages been regarded as a Planetary Body, and connected with the Solar System?

A. It has not.

Q. Why did the Ancients suppose it to be an Extended Plain?

A. They judged only from appearances.

Q. Did they suppose the Earth had any Motion?

A. They did not.

Q. What did they suppose held up the Earth?

A. They had no settled and well defined views on this point.

Q. In what direction did the Ancients suppose the Sun, Moon and Stars revolved?

A. They supposed that they revolved around the earth from east to west, every twenty-four hours.

Q. What was this system called that supposed the Earth to be at rest in the center of the Universe, with all the Heavenly Bodies revolving around it?

A. The Ptolemaic System, from Ptolomy, an Egyptian philosopher of the second century.

Q. We daily see the Sun rise in the East and set in the West. Where does it go during the night?

A. It appears to pass round under the earth. The stars, too, seem to pass round like the sun, under the earth every twenty-four hours.

Q. Is such really the case, or are these Motions only apparent?

A. They are not real, but are only apparent, and are

caused by the motion of the earth in the opposite direction, or from west to east.

Q. Do we see any Bodies that seem to rest on no foundations?

A. We see the sun and moon resting on nothing, and suspended in empty space.

Q. Is it not, then, reasonable to suppose that the Earth may rest on nothing?

A. It is as reasonable as that other of the heavenly bodies should have no foundations.

Q. If the Earth turns, and we are carried round with it, what will be the appearance of the Heavens?

A. They will appear to move round the earth in the opposite direction.

Q. How swiftly does the Earth Moove on its Axis?

A. Over one thousand miles per hour.

Q. How swiftly does the Earth Fly in its Orbit around the Sun?

A. About sixty-eight thousand miles per hour.

Q. Does the Earth Move in a Straight Line?

A. No. It is drawn from a straight to a curve line, by the attraction of the sun.

Q. Do any other Bodies Revolve around the Sun?

A. All the planets, both primary and secondary, do, as is shown on the Chart. The primary planets revolve directly around the sun as their center of motion, and the secondary planets or moons revolve around their primaries, and accompany them in their long journies around the sun.

## LESSON VI.

### CENTRIPETAL AND CENTRIFUGAL FORCES.

Q. What is the name of that Force that draws all bodies toward each other, in proportion to the quantity of matter they contain, and inversely, as the square of the distances of the attracting body?

A. The attraction of gravity or gravitation.

Q. Does this Force pervade the whole material Universe?

A. It undoubtedly does; and retains all the planets, satellites and comets of the solar system in their respective places, and binds the unnumbered millions of globes that belong to the universe into one vast and harmonious system.

Q. What is meant by Centripetal Force?

A. It is that attractive power or force which impels a body toward the center, round which it is revolving.

Q. Is there any large body in the Solar System that exerts a Centripetal Force upon the Planets and the Comets?

A. The sun, from his stupendous mass of matter, exerts such a force upon all the primary planets; that they are retained in their orbits, and none ever wander from its appropriate place from age to age.

Q. What retains the Moon in its Orbit around the Earth?

A. The earth and all the primary planets exert such a centripetal force upon their secondaries or moons.

Q. Why are not the Primary Planets attracted to the body of the Sun, and the Secondary Planets attracted to their primaries?

A. The centrifugal force they received when thrown from the hand of the Deity, impelling them to move off in straight lines, which is nicely adjusted to the centripetal force, and the combination of the two produces the curve line called a planetary orbit.

Q. Do the Planets move in Perfect Circles?

A. They do not. Their orbits are illiptical, as is seen in the figures A, P, B, D, E, C, S, on the left at the top of the Chart. The longest diameter is A, B, and the shortest is P, D. C, is the center of the ellipse, and S and E, are the foci around which the ellipse is formed.

Q. Is the Sun placed at the center of the Ellipse?

A. It is not. It is at S, the lower foci of the ellipse; and the distance from the center to either of the foci, which is equal, is called the eccentricity of the ellipse.

Q. When are Circles said to be in the same Plane?

A. When their planes are in a straight line; as if a number of concentric rings, or rings of different sizes, lay one within another upon the smooth surface of a table.

Q. Do the Orbits of all the Planets lie in the same Plane?

A. They do not. The orbit of Jupiter lies in the same plane as that of the earth; but the plane of all the rest rises above the ecliptic, or the plane of the earth's orbit; or one half of each rises above it, while the other half falls below it.

Q. Do the Planets all pass around the Sun in the same length of time?

A. They do not. They vary from 88 days to 164 years. The planets nearest the sun complete their revolutions in the shortest periods of time, and those most remote in longer periods.

Q. Do all the Planets move with equal Velocities?

A. They do not. The nearest planet to the sun moves 110 thousand miles per hour, while the most distant one known moves but 15 thousand miles per hour.

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## LESSON VII.—The Sun.

Q. What is the largest globe in the Solar System?

A. The Sun.

Q. What is the Size of the Sun?

A. It is about 880 thousand miles in diameter, and 2,264 thousand miles in circumference.

Q. Why does the Sun appear so small—only about the size of the Moon?

A. Because it is so far from the earth.

Q. What farther can you say of the Sun?

A. It is the great source of light, heat and attraction, and retains the planets in their orbits. Were the sun placed where the earth is, he would fill the space within the orbit of the moon, and extend 200 thousand miles beyond in every direction. It would require 112 such globes as the earth, if laid side by side, to reach across his vast diameter.

Q. Is the Sun larger than the Earth?

A. He is more than one million and three hundred thousand times as large as the earth.

Q. Are any of the Planets as large as the Sun?

A. They are not. The sun is 500 times larger than all the planets, satellites and comets in the system, taken together.

Q. What is the Mass or Weight of the Sun?

A. It is about 750 times that of all the planets.

Q. What is the Specific Gravity of the Sun?

A. About $1\frac{1}{3}$ the weight of water.

Q. What did Astronomers in the early ages suppose the Sun to be?

A. An immense ball of fire.

Q. Has the Sun any Motion?

A. It has three motions, as follows: 1. It revolves on its axis in $25\frac{1}{2}$ days. 2. Around the center of gravity of the solar system. 3. Around the center or capital of the universe.

Q. What is the Inclination of the Sun's Axis to that of the Ecliptic.

A. Seven and a half degrees.

Q. How is it known that the Sun Revolves on its Axis?

A. By spots, seen first on the east side, which pass over and disappear on the west side.

Q. What is the Nature of the Spots on the Sun?

A. Astronomers regard them as openings in the luminous atmosphere, enabling us to see the opaque body of the sun.

Q. Do the Spots on the Sun always appear of the same size?

A. They do not.

Q. What is the form of the Sun?

A. It is a globe, and not a flat surface, as it appears to the naked eye.

Q. What is the rate of the Sun's Motion at its Equator?

A. Not less than 4,532 miles an hour.

Q. What is the size and shape of the Spots on the Sun?

A. They are of all sizes and of different shapes.

Q. Is the Sun Inhabited?

A. Nothing is known to mortals on this subject.

Q. Will you mention some of the Advantages derived from the Sun?

A. It is the soul and center of a splendid retinue of revolving worlds.

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## LESSON VIII.

Q. What are the three great Laws discovered by Kepler?

A. 1. That all the planets perform their revolutions in elliptical orbits, having the sun in one of their foci. [See the ellipse, A, P, B, D, on the left, near the top of the Chart.] C, is the center of the ellipse, and E and S, are the foci. 2. That the radius vector passes over equal areas in equal portions of time.

Q. What is meant by the Radius Vector?

A. It is a line drawn from the sun to a planet in any

part of its orbit. In the ellipse, A, P, B, D, on the left, near the top of the Chart, the sun is at S, the lower foci. We will suppose the earth's orbit, where it is shown on the Chart in the twelve signs of the Zodiac, elliptical, like this figure (A, P, B,) a line drawn from the sun to the earth, where it will be on the first day of each month of the year, as it enters the several signs respectively, is the Radius Vector.

The third law discovered by Kepler is: that the squares of the times of the revolutions of the planets around the sun, are proportional to the cubes of their mean distances from the sun.

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## LESSON IX.—Mercury.

Q. Where is the proper place of Mercury in the Solar System?

A. Next to the sun, as shown on the Chart. The dark circle surrounding the sun, represents the orbit of the planet, and the two small circular figures, seen at the two opposite points of the circle or orbit, represent the planet itself, as seen in its inferior and superior conjunctions.

Q. What is the diameter of the Planet Mercury?

A. This planet is estimated at 32 hundred miles in diameter.

Q. How far is Mercury from the Sun?

A. Thirty-seven millions of miles.

Q. What is the Direction of the Planet in its Orbit around the Sun?

A. From west to east, as is indicated in the direction of the earth, by the months of the year in the third orbit from the sun, on the Chart.

Q. What is the Rate of Motion of this Planet in its Orbit?

A. One hundred and ten thousand miles per hour.

Q. What is the Specific Gravity of the Planet Mercury?

A. It is about 15 times the weight of water.

Q. How many Conjunctions has Mercury?

A. Two; an inferior and a superior conjunction.

Q. Can Mercury have an Opposition as well as his Conjunctions?

A. It cannot, because its orbit lies between the earth and the sun.

Q. Do the Mean and True places of a Planet's Orbit ever coincide?

A. They do, at the aphelion and perihelion, as at A and B, in the ellipse, on the Chart.

Q. What is the straight line called that passes through the Sun from A to B, in the Ellipse?

A. It is called the apsis line.

Q. Is the Planet ever behind its Mean Place?

A. It is; as when it is passing from its perihelion at B, to its aphelion at A, in the ellipse.

Q. When is it before its Mean Time?

A. When it is passing from its aphelion at A, its greatest distance from the sun, to its perihelion B, its least distance. [See the Ellipse.]

Q. When does a Planet Move with its least Velocity?

A. When it is farthest from the sun, or in its aphelion, as at A, in the ellipse.

Q. Why is this so?

A. Because the attractive influence of the sun is diminished as the planet recedes from it.

Q. When is the Motion of the Planet Increasing?

A. When it is passing from A, its aphelion, to B, its perihelion, as in the ellipse.

Q. What causes this Accelerated Motion?

A. The increased force of the sun's attraction on the planet, as it approaches nearer the sun.

Q. What causes the Planet to Recede from the Sun, from its Perihelion at B, to its Aphelion at A?

A. The superior centrifugal force of the planet here, just obtained by the sun's attraction as it advanced with increased velocity toward the sun.

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## LESSON X.—Mercury—*Continued.*

Q. When is Mercury said to be in his Inferior Conjunction?

A. When he is between us and the sun. Thus, when the earth is in that part of its orbit, marked in the Diagram as "September," and "Mercury" is where his name is red, he is in a direct line with the sun from our standpoint of observation. He is then between us and the sun. This is called his "inferior conjunction."

Q. When is Mercury said to be in his Superior Conjunction?

A. When he is in a direct line from our post of observation, beyond the sun. [See the Diagram, where another very small circular figure is shown on the opposite side of the circle, in a direct line from our post of observation on the earth, where it is marked "September."] This is Mercury, in his superior conjunction.

Q. Why is he shown on the Chart as appearing smaller in his Superior than in his Inferior Conjunction?

A. Because he is farther from us now, by the whole diameter of his orbit, and hence he will appear much smaller than when he is nearest us, as in his inferior conjunction.

Q. What is the Year of a Planet?

A. The time it takes to revolve around the sun.

Q. What is the Year of Mercury?

A. Eighty-seven days and twenty-three hours of our time. But from one conjunction to the same conjunction again, it is about 116 days.

Q. What is Mercury called?

A. An "interior planet."

Q. Why is Mercury called an Interior Planet?

A. Because its orbit lies within the earth's orbit, or between the earth and the sun. The same is true of Venus. [See the Diagram.]

Q. What are all the other Planets of the Solar System termed?

A. "Exterior planets;" because they perform their revolutions in orbits which lie beyond the earth's orbit.

Q. What is the Density of Mercury?

A. It is about equal to that of lead.

Q. How Swiftly does the Planet fly?

A. About 1,830 miles in a minute, and about 30 miles in a second.

Q. What is the Light and Heat of Mercury, compared with that of the Earth?

A. It is about seven times greater.

Q. What is the Elongation of a Planet?

A. The apparent distance of a planet from the sun.

Q. What is the greatest Elongation of Mercury?

A. Thirty degrees either west or east from the sun.

Q. Has Mercury any Change of Seasons?

A. It has not.

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## LESSON XI.—Venus.

Q. What Planet is next to Mercury, in the Arrangement of the Solar System?

A. Venus.

Q. What is the Diameter of Venus?

A. Seven thousand eight hundred miles.

Q. How far is Venus from the Sun?

A. Sixty-nine millions of miles.

Q. In what time does she Revolve around the Sun?

A. Two hundred and twenty-five days—at the rate of 75 thousand miles an hour.

Q. What is the Circumference of her Orbit?

A. Four hundred millions of miles.

Q. What is the Specific Gravity of Venus.

A. About five times the weight of water.

Q. What is the comparative Light and Heat of Venus?

A. It is about double that of the earth.

Q. What is the greatest Elongation of Venus?

A. About 47 degrees.

Q. How near does the Planet ever approach to the Earth?

A. When she is in that part of her orbit nearest the earth, as shown in the figure, she is 27 millions of miles distant from us.

Q. When is Venus the Morning Star?

A. When she is west of the sun, and rises before it.

Q. When is she an Evening Star?

A. When she is east of the sun, and sets after it.

Q. How long does she continue to be a Morning Star?

A. About 270 days; and then the same length of time as an evening star.

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## LESSON XII.—VENUS—*Continued.*

Q. Why is Venus a Morning and an Evening Star, about 66 days longer than the whole time of her Annual Revolution around the Sun?

A. Because, the earth is moving, though not so swiftly, around the sun in the same way. Venus will move 180 degrees of her orbit, while the earth is moving only 110 degrees. If the earth stood still, or kept up with Venus, the result would be essentially varied.

Q. Can any other Planet approach so near the Earth as Venus?

A. No. An inspection of the Diagram will show that no other planet of the solar system can approach so near the earth as this.

Q. How much is the Axis of Venus inclined to that of its Orbit?

A. Seventy-five degrees; so that its torrid zone will be 150 degrees wide, or 75 on each side of its equator.

Q. Does this Planet ever assume Different Phases, like the Moon?

A. She does.

Q. Has Venus any Variations of Seasons?

A. She has eight seasons—two summers and two winters at the equator; and a summer and winter at each of the poles during the year.

Q. Why does Venus assume the Phases of the Moon?

A. Because, she revolves in an orbit between the earth and the sun.

Q. How many apparent Motions have the Planets?

A. Three; direct, stationary and retrograde.

Q. When is the Motion of a planet said to be direct?

A. When it appears to move from west to east, among the stars.

Q. When is it said to be Stationary?

A. When it appears to be moving directly towards, or from the earth.

Q. When is it Retrograde?

A. When it seems to move backwards, among the stars.

Q. Is Venus attended with a Satellite or Moon?

A. This question is not positively decided among astronomers.

## LESSON XIII.—The Earth.

Q. What is the form of the Earth?

A. It is that of an oblate spheriod, nearly approaching to that of a globe.

Q. What is the place of the Earth in the Solar System?

A. The path of the earth around the sun, lies between the paths or orbits of Venus and Mars. [See the Chart.]

Q. How do the Inhabitants Stand upon the Earth?

A. With their feet toward the center of the earth.

Q. What keeps the Inhabitants on the Earth.

A. The attraction of the earth.

Q. What does the Earth rest on?

A. It rests on no foundation; but it is a planetary body suspended in empty space, and surrounded on all sides by the starry heavens.

Q. What is the Axis of the Earth?

A. A straight line round which it performs its diurnal rotation; and the extremity of its axis are the poles of the earth.

Q. What is the Distance of the Earth from the Sun?

A. About 95 millions of miles.

Q. What, then, is the Diameter of the Earth's Orbit?

A. Twice its distance from the sun—190 millions of miles.

Q. What is the Circumference of the Earth's Orbit?

A. About 600 millions of miles.

Q. How long does it take the Earth to perform a Journey Round the Sun?

A. Three hundred and sixty-five and a quarter days.

Q. With what Velocity must the Earth Move, to complete this revolution in this length of time?

A. About 68 thousand miles an hour.

Q. What is the Equator?

A. It is the great circle whose plane divides the earth into northern and southern hemispheres. This plane is perpendicular to the earth's axis, and is at an equal distance from each pole.

Q. What is the Meridian of a place on the Earth?

A. A great circle passing through a place, and extending from pole to pole; and the plane of this meridian divides the earth into eastern and western hemispheres.

Q. What is the Latitude of a place on the Earth?

A. Its distance from the equator, north or south.

Q. On what is Latitude measured?

A. On a meridian, and is reckoned 90 degrees.

Q. What places on the Earth have 90 Degrees of Latitude?

A. The north and south poles.

QUESTION ON THE CHART.

Q. Why is every Planet, Satellite and Comet there shown with an Enlightened Side toward the Sun?

A. Because they receive their light from the sun.

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## LESSON XIV.

### VARIETY OF SEASONS ON THE EARTH.

Q. What causes the Changes of the Seasons on the Earth?

A. The annual revolution of the earth around the sun, in connection with the inclination of its axis, in an angle of 23½ degrees from the perpendicular to the plane of the ecliptic.

Q. How many Seasons have we on the Earth?

A. Four; spring, summer, autumn and winter.

Q. Can you explain from the Chart, what is meant by the Inclination of the Earth's Axis?

A. N. and S., on the Chart, where the earth is marked "March" and "September," will designate the north and south poles of the earth respectively. A straight line from N. to S., it is readily seen, would not stand perpendicular, but would be inclined from the perpendicular in an angle of 23½ degrees. It is seen from the Diagram, that the axis stands thus permanently inclined through every month of the year, and during the entire journey of the earth around the sun. "This permanent inclination of the earth's axis from the perpendicular, and her revolution around the sun, cause first one pole to be enlightened, and then the other, thus producing the seasons. The same inclination and revolution, cause the sun to appear to oscillate from north to south, crossing the equator twice every year." This is called the "sun's declination."

Q. At what times of the year are the Days and Nights of Equal Length?

A. On the 21st of March and on the 23d of September.

Q. What causes this Equality of Day and Night at those times?

A. The sun, shining equally from pole to pole. [See the Diagram.]

## LESSON XV.

Q. What is the Diameter of the Earth?

A. Seven thousand nine hundred and thirty miles.

Q. How much greater is its Equatorial than its Polar Diameter?

A. About 26 miles; and is caused by the revolution of the earth on its axis.

Q. What is the Specific Gravity of the Earth?

A. It is about $5\frac{1}{2}$ times the weight of water.

Q. In what Time does the Earth Revolve on its Axis, or complete an entire Rotation?

A. In 24 hours.

Q. Which Way does the Earth Turn on its Axis?

A. From west to east, as all the planets in the solar system do.

Q. What results from this Rotation?

A. Day and night.

Q. What portion of the Earth's Surface has Light, and what portion Darkness?

A. One half of the earth's surface is continually in the light of the sun, while the other half is continually in the dark.

Q. Is the Earth ever Behind Time in its Rotation on its Axis?

A. No. It is uniform and exact to the second, from age to age. God has covenanted that there shall always be day and night in their seasons.

## LESSON XVI.—The Seasons—*Continued.*

Q. When does the North Pole of the Earth, lean directly toward the Sun?

A. On the 21st of June, called the "summer solstice." [See the Diagram.]

Q. Can you Illustrate clearly the gradual Changes of the Seasons from the Chart?

A. On the 21st of March, the Diagram shows the sun shining equally on both poles of the earth. This is the reason why we have equal day and night at that time. So of the 23d of September, shown in the opposite side of the earth's orbit. But as the earth moves onward in her orbit, from her place in March, in the period of a month, she has traveled about 50 millions of miles, and her north polar circle is seen advancing farther into the light, and her south polar circle a corresponding extent into the dark. When the 21st of June has rolled around, and the earth has traveled 100 millions of miles farther in its orbit, the north polar circle is seen wholly in the light of the sun, and the south polar circle, at the same time, wholly in the dark. The axis of the earth is always parallel to itself, pointing in the same direction in the heavens. On the 21st of June, the sun ceases to decline from the equinoctial and to return towards it. This is called the "summer solstice." "The equinoctial points are two opposite sides of the earth's orbit, at which time the sun is exactly in the equinoctial; or in other words, the plane of the equinoctial cuts the sun's center," and the sun shines equally from pole to pole. The first of the equinoctial

points, when, of course, the days and nights are equal, is reached by the earth in her flight around the sun, on the 21st of March.

Q. What is this called?

A. The "vernal equinox."

Q. When is the other Equinox, and what is it called?

A. The 23d of September, and is called the "autumnal equinox." When the earth has advanced to 90 degrees, or one-fourth part of her orbit, the sun ceases to decline from the equinoctial or equator, and begins to return toward it, as shown on the Chart, in the month of June.

Q. How many Degrees does the North Pole of the Earth lean towards the Sun on the 21st of June?

A. Twenty-three and a half degrees; and the sun is vertical 23½ degrees north of the equator.

Q. Does this produce any Difference of Seasons from any other time of the year?

A. It produces summer in the northern hemisphere, and winter in the southern. An inspection of the Diagram will show this clearly.

Q. When does the North Pole lean directly from the Sun?

A. On the 21st of December, called the "winter solstice." [See the Diagram or Chart, where the north pole is turned from the sun, and is wholly in the shade, while the south pole is in the light.]

Q. What are the Seasons when the North Pole leans from the Sun?

A. Winter in the northern hemisphere, and summer in the southern.

## LESSON XVII.—The Seasons—*Continued.*

Q. Why are the Days the Longest, and the Nights the Shortest, on the 21st of June, in the Northern Hemisphere?

A. Because the most of the northern hemisphere is then in the light of the sun.

Q. Why are the Nights the Longest, and the Days the Shortest, at the time of the Winter Solstice, on the 21st of December?

A. Because the largest part of the northern hemisphere is then turned from the sun, and is in the shade,

Q. How far are the Solsticial Points from the Equinoctial Points?

A. Ninety degrees. All circles are divided into 360 parts, called degrees; and the solsticial points are respectively 90 degrees, or one-fourth part of the earth's orbit, from the equinoctial points.

Q. When is the Summer Solstice Reached by the Earth in its Annual Journey around the Sun?

A. On the 21st of June, when the sun has the greatest northern declination, or is at its greatest distance north of the equinoctial, and it pours a flood of welcome light on all the region of the globe embraced within the north polar circle. The light and shade on the figure, shown on the Chart at this time, will show why it is summer in the northern hemisphere—so large a portion of this hemisphere being in the light of the sun.

Q. When is the Winter Solstice Reached by the Earth, as it flies around the Sun?

A. On the 21st of December, when the sun is at its greatest distance south of the equinoctial; or in other words, has the greatest southern declination, as in the figure, and it is summer in the southern hemisphere, and winter in the northern. [See the Earth, in the Diagram, in June and December.]

Q. How far does the Sun Decline to the North and South of the Equinoctial?

A. About 23½ degrees, answering to the inclination of the earth's axis from the perpendicular, by which it is caused, and marking the limits of the tropics upon the earth's surface.

Q. How long have the North and South Poles of the Earth the Light of the Sun, respectively?

A. The north pole of the earth has the light of the sun, from the vernal equinox, on the 21st of March, to the autumnal equinox, on the 23d of September; and then the south pole advances into the light, which it continues to enjoy until the 21st of March.

Q. Is this an Equal Division of the Year, giving to each Pole the Light of the Sun just one-half of the time?

A. No. The north pole has the light of the sun about eight days longer than the south pole.

Q. How is this produced?

A. The orbit of the earth is elliptical, and the earth has to pass through 180 degrees of its orbit, which occupies 186 days 11 hours; but while the earth is passing through the other part of its orbit, from the 23d of September to the 21st of March, it passes through only 176 degrees, which is performed in 178 days 18 hours. As the earth

moves in an elliptical orbit, it is farther from the sun in the northern than in the southern hemisphere, and as a result, moves slower.

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## LESSON XVIII.—The Seasons—*Continued.*

Q. What causes the North Pole to have the Light of the Sun for six months, and then to be deprived of the light the balance of the year?

A. The earth's revolution round the sun. The Diagram shows the sun shining on the north pole for six months, and the south pole deprived of his light for the same length of time. From March 21st to September 23d, the sun shines without intermission on the north pole, and during this time the south pole is in the dark. At these points, it is equal day and night, because both poles are equally enlightened by the sun. But from March to June, the larger portion of the northern hemisphere is in the light of the sun, and the rotation of the earth on its axis gives us a longer day than night. As the poles of the earth always point in the same directions in the heavens, it will be seen by the Diagram that it is the earth's revolution around the sun that brings first one pole of the earth into the light of the sun for six months, and then in turn the other.

Q. Why are not the Days and Nights of Equal Length at all times of the year?

A. It is owing to the inclination of the earth's axis, in connection with its revolution around the sun, that we

have a difference in the length of day and night, at different periods of the year. The light and shade shown on the earth from March 21st to June 21st, in the Diagram, presents a gradual increase of enlightened surface on the northern hemisphere.

Q. Does the Diagram show the Light and Shade exactly as they are on the Earth at all times?

A. The light and shade on the earth during the several months of the year, in the Diagram, are not designed to exhibit the exact quantity of light and shade on any *particular portion of the earth;* but rather the proportions of light and shade on the two hemispheres. The figure shows, that while one pole of the earth is in the dark, being deprived of the light of the sun, the other pole is, to a corresponding extent, in the light. But while exhibiting these facts, it is impracticable to have, on a plane surface like the Diagram, all the enlightened parts of the earth appear as turned toward the sun, and all its unenlightened parts appear as turned from it.

Q. What is the Length of Day and of Night at the Poles?

A. Six months.

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## LESSON XIX.—The Zodiac.

Q. What is the Zodiac?

A. By the "zodiac," is meant an imaginary belt, 16 degrees wide, viz: 8 degrees on each side of the ecliptic, and extending from west to east, quite round the heavens.

Q. What is meant by the Signs of the Zodiac?

A. Certain clusters of stars, situated in twelve different parts of that great circle of the heavens through which the sun *appears to move*, and through which the earth *actually does move*, in its annual journeys.

Q. Who Invented the Constellations forming the Zodiac?

A. It was probably the work of the Egyptians and Chaldeans.

Q. How is the Zodiac Divided?

A. Into 12 equal parts, called "constellations," or the "signs of the Zodiac;" and each sign is divided into 30 degrees; each degree into 60 minutes; each minute into 60 seconds, &c.

Q. Where is the Ecliptic or Orbit of the Earth?

A. It is in the middle of the Zodiac.

Q. Will you give the Names of the Constellations of the Zodiac?

A. Aries, (or the Ram,) Libra, (the Balance,)
Taurus, (the Bull,) Scorpia, (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.)

Q. What is the Order of the Signs around the Heavens

A. Beginning at Aries, eastward, around to Pisces.

Q. Are the Constellations of the Zodiac and the Signs of the Ecliptic in the same place in the Heavens?

A. They were about 2,200 years ago; but the signs of

the ecliptic have fallen back of the constellations about 31 degrees, caused by the retrograde motion of the equinoxes.

Q. Upon what does the Length of the Seasons Depend?

A. The revolution of the earth from one equinox to the same equinox again.

Q. Does the Earth Move from one Equinox to the same again, in exactly the time it Revolves around the Sun?

A. It requires 17 minutes longer to revolve around the sun.

Q. Does the Sun revolve around the Heavens?

A. The sun has only an *apparent*, and not a *real*, motion among the stars, from east to west, caused by the actual motion of the earth from west to east.

Q. Where is the Real Place of the Earth in March?

A. In Libra, and consequently the sun will appear in the opposite sign, Aries, and be vertical to the equator, as shown in the figure of the earth at that place.

Q. Where is the Earth in June?

A. In Capricorn; and the sun is in the opposite sign, Cancer, when he is vertical to those who live under the tropic of Cancer.

Q. Where is the Place of the Earth in September?

A. In Aries, and the sun is in the opposite sign, Libra, when he is again vertical to the equator,

Q. Where is the Earth in December?

A. In Cancer, and the sun in Capricorn, when he is vertical to those living under the tropic of Capricorn, as the inhabitants of the southern parts of Africa and the central parts of New Holland.

Q. What are the Spring Signs of the Ecliptic?

A. Aries, Taurus, Gemini.

Q. What are the Summer Signs?

A. Cancer, Leo, Virgo.

Q. Which are the Autumnal Signs?

A. Libra, Scorpio, Sagittarius.

Q. Which are the Winter Signs?

A. Capricornius, Aquarius, Pisces.

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## LESSON XX.—Mars.

Q. What is the Place of Mars in the Solar System?

A. Mars is the fourth planet from the sun.

Q. What is the Size of Mars?

A. It is the smallest in the solar system, except Mercury and the Asteroids. It is 4,200 miles in diameter.

Q. What is the Periodic Time of Mars?

A. Six hundred and eighty-seven days, or one year and 322 days of our time.

Q. What is the Distance of Mars from the Sun?

A. One hundred and fourty-five millions of miles.

Q. What is the Specific Gravity of this Planet?

A. About five times the weight of water.

Q. How many Degrees does the Axis of Mars Lean towards its Orbit?

A. About 30 degrees.

Q. Has this Planet any Change of Seasons?

A. It has. Its seasons will vary but little from ours, as

its axis are inclined only $6\frac{1}{2}$ degrees more than those of the earth's.

Q. What is the Length of its Day and Night?

A. About the same as ours. The day of Mars differs but 44 minutes from the day of our globe.

Q. What way does it Revolve in its Diurnal and Annual Revolutions?

A. From west to east.

Q. What is the Length of the Seasons of Mars?

A. About twice the length of ours.

Q. What is the Appearance of Mars when seen through a Telescope?

A. A red fiery color.

Q. What amount of Light and Heat has Mars?

A. About half as much as the earth.

Q. Does the Bright Appearance about its Poles continue during the Whole of its Year?

A. It disappears during the summer.

Q. What does the Striking Resemblance between this Planet and the Earth Indicate?

A. That the design of the Creator was not essentially different in its formation from that of the earth. It has all the arrangements essentially requisite to its being a habitable world.

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## LESSON XXI.—MARS—*Continued.*

Q. Is Mars an Interior or Exterior Planet?

A. Mars is an exterior planet, because it performs its

annual journies around the sun in an orbit lying exterior to the orbit of the earth.

Q. How many Conjunctions have the Interior Planets?

A. Two. [See Mercury and Venus, in the Diagram, and Lesson X.]

Q. How many Conjunctions have the Exterior Planets?

A. One conjunction and one opposition.

Q. When is Mars in his Conjunction?

A. When he is beyond the earth, in the same part of the heavens as the sun.

Q. When is he in Opposition?

A. When the earth is between him and the sun. This will readily be understood by the Diagram. When the earth is at the place in her orbit, designated as "September," and Mars is at the place in his orbit where his name is red, he is then said to be in his "opposition;" and when he is seen on the opposite side of his orbit, he is then said to be in his "conjunction," because he is then in the same part of the heavens as the sun. The small circular figure seen at that point, is Mars, in his conjunction.

Q. Why does he Appear so much Smaller on the Opposite Side of his Orbit?

A. At distances so essentially different, it will necessarily result that his apparent magnitude will not always be uniform.

Q. How Far is Mars from the Earth when at his Greatest Distance?

A. Two hundred and forty millions of miles.

Q. How Near to the Earth does this Planet ever Approach?

A. Fifty millions of miles. When nearest the earth, he is nearer by the whole diameter of the earth's orbit, or 190 millions of miles. This will appear by an inspection of the Diagram at this point.

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## LESSON XXII.—The Asteroids.

Q. What are the Asteroids?

A. They are small planets; and all perform their revolutions between the orbits of Mars and Jupiter—a space of about 349 millions of miles.

Q. How Many Asteroids are there?

A. Fifty-seven, so far as now known.

Q. What is the Magnitude of the Asteroids?

A. They are all small, probably less than our moon.

Q. Do they all Revolve in Orbits Similar to the other Planets?

A. Some of their orbits are more eccentric, and the orbit of Pallas crosses the orbits of other planets.

Q. What are the Names of the Asteroids, and the Date of their Discovery?

A.

| No. | Name. | Date of Discovery. |
|---|---|---|
| 1. | Ceres, ..... | |
| 2. | Pallas, ..... | 1801, Jan. 1. |
| 3. | Juno, ..... | 1802, Mar. 28. |
| 4. | Vesta, ..... | 1804, Sept. 1. |
| 5. | Astæa, ..... | 1807, Mar. 20. |
| 6. | Hebe, ..... | 1845, Dec. 8. |
| 7. | Iris, ..... | 1847, July 1. |
| 8. | Flora, ..... | 1847, Aug. 13. |
| 9. | Metis, ..... | 1847, Oct. 18. |
| 10. | Hydea, ..... | 1848, Apr. 25. |
| 11. | Porthenope, | 1849, Apr. 12. |
| 12. | Clio, ..... | 1850, May 13. |
| 13. | Egeria, ..... | 1850, Sept. 13. |
| 14. | Irene, ..... | 1850, Nov. 2. |
| 15. | Eunomia, .. | 1851, May 20. |
| 16. | Psyche, .... | 1851, July 29. |

| No. | Name. | Date of Discovery. |
|---|---|---|
| 17. | Thetis, | 1852, Mar. 17. |
| 18. | Melpomene, | 1852, Apr. 17. |
| 19. | Fortuna, | 1852, June 24. |
| 20. | Massilia, | 1852, Aug. 22. |
| 21. | Lutetia, | 1852, Sept. 19. |
| 22. | Calliope, | 1852, Nov. 15. |
| 23. | Thalia, | 1852, Nov. 16. |
| 24. | Themis, | 1852, Dec. 15. |
| 25. | Procea, | 1853, Apr. 5. |
| 26. | Proserpina, | 1853, Apr. 6. |
| 27. | Euterpa, | 1853, May 5. |
| 28. | Bellona, | 1853, Nov. 8. |
| 29. | Amphitrite, | 1854, Mar. 1. |
| 30. | Urania, | 1854, July 22. |
| 31. | Euphrosine, | 1854, Sept. 1. |
| 32. | Pomona, | 1854, Oct. 26. |
| 33. | Polyhymnia, | 1854, Oct. 28. |
| 34. | Circe, | 1855, Apr. 15. |
| 35. | Leucothea, | 1855, Apr. 19. |
| 36. | Atalanta, | 1855, Oct. 5. |
| 37. | Fides, | 1856, Oct. 5. |
| 38. | Leda, | 1856, Jan. 12. |
| 39. | Lastetia, | 1856, Feb. 8. |
| 40. | Harmonia, | 1856, Mar. 31. |
| 41. | Daphne, | 1856, May 23. |
| 42. | Isis, | 1856, May 25. |
| 43. | Ariadne, | 1857, Apr. 15. |
| 44. | Nysa, | 1857, May 27. |
| 45. | | 1857, June 27. |
| 46. | Hestia, | 1857, Aug. 16. |
| 47. | Aglaia, | 1857, Sept. 16. |
| 48. | Doris, | 1857, Sept. 19. |
| 49. | Pales, | 1857, Sept. 19. |
| 50. | Virginia, | 1857, Oct. 4. |
| 51. | Nemansa, | 1858, Jan. 22. |
| 52. | Europa, | 1858, Feb. 4. |
| 53. | Calypso, | 1858, April 4. |
| 54. | Alexandria, | 1858, Sept. 11. |
| 55. | Pandora, | 1858, Sept. 11. |
| 56. | Melete, | |
| 57. | Mnemosyne, | |

Q. In what Length of Time do the first four of these Planets Revolve around the Sun?

A. Vesta, in one thousand three hundred and thirty-one days.

Q. What is the Periodic Time of Juno?

A. One thousand five hundred and ninety-three days.

Q. What is the Periodic Time of Ceres?

A. One thousand six hundred and eighty-one days.

Q. What is the Periodic Time of Pallas?

A. One thousand six hundred and eighty-seven days.

Q. Are any of the Asteroids or Small Planets attended with Satellites?

A. This question is not positively decided among astronomers.

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## LESSON XXIII.—Jupiter.

Q. What is the Name of the next Planet beyond the Asteriods?

A. In the arrangement of the solar system, Jupiter is placed next in order beyond the asteroids. His orbit lies between the asteroids and that of Saturn.

Q. How Large is Jupiter?

A. Jupiter is the largest planet in the solar system yet discovered, being nearly 89 thousand miles in diameter, making it over 14 hundred times as large as the earth.

Q. How Far is Jupiter from the Sun?

A. Four hundred and ninety-five millions of miles.

Q. How Near does this Planet ever Approach to the Earth?

A. When nearest the earth, Jupiter is about 400 millions of miles from us.

Q. How Far is he Ever from the Earth?

A. When farthest off, he is 590 millions of miles distant, being, as will be seen by the figure, farther by the whole diameter of the earth's orbit, which is 190 millions of miles.

Q. Which Diameter of this Planet is the Greatest, the Polar or the Equatorial?

A. The equatorial diameter is 6,000 miles greater than the polar, which results from the very rapid rotation of the planet on its axis.

Q. In what Time does it Revolve on its Axis?

A. In about ten hours and a half.

Q. What is the Velocity of its Equatorial Parts in Turning on its Axis?

A. Twenty-eight thousand miles an hour—3,000 miles more than the equatorial parts of the earth's surface move in 24 hours.

Q. How Many Days are there in the Year of Jupiter?

A. Ten thousand four hundred and seventy.

Q. What Amount of Light and Heat has this Planet?

A. It has about 27 times less light than the earth.

Q. Will there be any considerable Difference in the Length of the Days and Nights of Jupiter?

A. There will be nearly equal day and night in every part of the surface of this planet; but the sun will rise to a high elevation above its horizon to places near the equator.

Q. How Many Moons has Jupiter?

A. Jupiter is attended by four moons. In the Diagram they are shown in their orbits at different distances from the planet.

Q. What is the Direction of the Moons of Jupiter?

A. They all move from west to east, according to the order of the signs, as do all the planets of the system.

Q. From What Source do they Derive their Light?

A. From the sun.

Q. How does Jupiter Appear when Viewed with a Telescope?

A. The disc of Jupiter is streaked with curious belts, running parallel to his equator.

Q. Who first Discovered the Moons of Jupiter?

A. Galileo, the inventor of the telescope, in 1610.

Q. What is their Magnitude?

A. The magnitude of these satellites differ but little from that of our moon. The third one, however, is somewhat larger.

Q. How are the Orbits of the Moons of Jupiter Situated?

A. They are directly over his equator.

Q. What are the Periodic Times of their Revolutions?

A. They perform their revolutions in periods of from one day 18½ hours, to 16 days 16 hours, according to their distances.

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## LESSON XXIV.—JUPITER—*Continued.*

Q. What are the Magnitudes and Distances of Jupiter's Moons?

A. Their magnitudes and distances are as follows?

DIAMETER IN MILES.

| | |
|---|---|
| First,.....2,500. | Third,.....3,777. |
| Second,.....2,068. | Fourth,.....2,890. |

DISTANCE FROM THE PRIMARY:

From 260,000.....to 1,180,000.

Q. Do the Moons of Jupiter ever Suffer Eclipses?

A. The planet is shown in the Diagram as casting a shadow in the direction opposite to the sun. Its moons or satellites, in revolving around it, will frequently fall into its shadow, and will suffer numerous eclipses. The

satellites of Jupiter pass through this broad shadow, when in opposition to the sun, and are totally eclipsed at every revolution. The fourth satellite, however, sometimes passes above, and sometimes below, and thus escapes being eclipsed. These moons often eclipse Jupiter, by throwing their dark shadows upon his disc, as is seen on the Chart, in the case of the fourth moon. About forty of these eclipses occur in the system of Jupiter every month.

Q. What great Discovery was Made by Observing the Eclipses of Jupiter's Moons?

A. It was by observations upon the eclipses of Jupiter's moons, as compared with the tables fixing the time of their occurrence, that it was discovered that light had a progressive motion of about 192 thousand miles per second.

Q. Will you Illustrate this from the Chart?

A. The orbits of Jupiter and the Earth are concentric, and hence the mutual distances of these globes will be continually varying. Direct your attention to Jupiter, with his system of moons, and to the Earth in its orbit around the sun. It is evident that when the Earth is in that part of its orbit designated as "December," it will be the whole diameter of its orbit, which is 190 millions of miles farther from Jupiter than when he is at the place in his orbit, marked as "June." If light were instantaneous, the satellite now seen immersed in Jupiter's shadow, would appear to enter into this shadow, to a spectator on the earth, when it is farthest distant from Jupiter, as in "December," at the same moment as to another spectator,

when the earth is nearest, as in "June;" but from numerous observations, it was found that when the earth was at its greatest distance from the planet, the immersion of the satellite into the shadow of the planet, happened 16 minutes and 22 seconds later than when the earth was nearest, as in "June."

Q. What Conclusions were drawn from this?

A. It was therefore concluded that light was not instantaneous, but requires a certain space of time to fly from one part of the universe to another, and that the time it takes in passing from the sun to the earth, or across the semi-diameter of the earth's orbit, is 8 minutes and 13 seconds, giving it a motion of 192 thousand miles per second—a motion of more than 10 thousand that of a cannon ball when first projected from the cannon's mouth.

Q. What is the Density of Jupiter?

A. About $1\frac{1}{4}$ that of the earth.

Q. How was the Rotation of the Planet and the Length of its Day Determined?

A. By watching spots in the belts of the planet.

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## LESSON XXV.—Saturn.

Q. What is the Next Planet in the Solar System beyond the Orbit of Jupiter?

A. Saturn, at the distance of 907 millions of miles from the sun, and about 412 millions of miles beyond the orbit of Jupiter.

Q. What is the Size of the Planet Saturn?

A. He is about 79 thousand miles in diameter, and about 1,000 times larger than the earth.

Q. What is the Specific Gravity of Saturn?

A. About the same as that of cork, or about one-half the weight of water.

Q. In what Time does this Planet Revolve on its Axis?

A. Ten hours and 16 minutes.

Q. How Many Days will this Planet have in its Year?

A. Twenty-five thousand one hundred and fifty.

Q. What is its Motion on its Axis at the Equator?

A. It is about 24 thousand miles an hour—2,000 miles greater than its rate of motion in its annual revolution around the sun.

Q. Is there any Change of Seasons at Saturn?

A. There is, but the change comes very slow, as it requires nearly thirty of our years to complete a year at Saturn.

Q. How Long does it take this Planet to Perform a sideral Revolution Around the Sun?

A. Twenty-nine and a half years.

Q. What is the Circumference of his Orbit?

A. A distance of about 5,700 millions of miles.

Q. What surrounds Saturn?

A. Saturn is encircled by two magnificent rings.

Q. What is the Position of these Rings in Reference to the Planet?

A. They are directly over its equator.

## LESSON XXVI.—SATURN—*Continued.*

### QUESTIONS ON THE CHART.

Q. How and Where is Saturn Shown in the Diagram?

A. Saturn, with his suite of rings, is shown in perspective in its orbit, "S." near the lower side of the Chart; but he is more accurately exhibited, with his rings and moons on the opposite side of his orbit, near the top of the figure.

Q. How are the Rings Shown there?

A. In a circular form. Our view of the planet is generally an oblique one, and hence these rings never appear circular, but usually elliptical. If either pole of the planet were exactly towards us, we should have a perpendicular view of the rings.

Q. What are the Dimensions of these Rings, in round numbers?

Miles.

A. Distance from the planet to the first ring, 19,000.
Width of the interior ring,.....17,000.
Space between the interior and exterior rings, 2,000.
Width of the exterior ring,.....10,000.
Thickness of the rings, ..... 100.
Exterior diameter of exterior ring,.....176,418.
Interior diameter of exterior ring, .....155,272.
Exterior diameter of interior ring,.....151,690.
Interior diameter of interior ring, .....117,339.

Q. What Good Purpose do these Rings Answer to the Planet?

A. They serve as reflectors to throw the light of the sun upon the planet, as our moon does upon the earth.

Q. How Many Satellites or Moons has Saturn?

A. Eight.

Q. Do they Revolve with the Planet and Rings?

A. These moons and rings all revolve with the planet.

Q. What is the Position of the Orbits of Saturn's Moons?

A. All of them, excepting one, are directly over the rings.

Q. What is the Form of the Orbits of Saturn's Moons?

A. The moons of Saturn revolve in orbits nearly circular.

Q. How Near are these Moons to the Planet?

A. Their mean distances from the planet, are from 123,000 to 2,366,000 miles.

Q. In how long a Time do they perform their Revolutions around the Planet?

A. They perform their sideral revolutions around their primary, in periods of from 22½ hours to 79 days, according to their distances.

Q. Do the Satellites of Saturn ever Suffer Eclipses?

A. They are seldom eclipsed. Yet they may be on rare occasions, as shown in the Diagram, in the case of the third from the planet.

Q. What will Result from the Small Density and Rapid Rotation of the Planet on its Axis?

A. It will materially diminish its otherwise attractive force, and contribute, in accordance with the great law of gravitation, to retain the rings and moons in the places assigned them in the system of Saturn.

## LESSON XXVII.

### URANUS.

Q. When, and by Whom, was Uranus Discovered?

A. In 1781, by Sir William Herschel, a celebrated English astronomer.

Q. What is the Distance of this Planet from the Sun?

A. Its distance, in round numbers, is 1,850 millions of miles.

Q. What is the Diameter of Uranus?

A. About 35 thousand miles, making it about 8 times as large as the earth.

Q. What is its Specific Gravity?

A. It is $1\frac{1}{2}$ times the weight of water.

Q. In What Part of the Solar System is Uranus situated?

A. Uranus is the seventh large planet from the sun, and revolves in an orbit lying between Saturn and Neptune.

Q. What is its Rate of Motion in its Orbit?

A. Fifteen thousand miles an hour.

Q. In How Long a Time does it Revolve Around the Sun?

A. Eighty-four years.

Q. What Place in the Solar System was Uranus Supposed to hold at the Time of its Discovery?

A. At the time of its discovery, it was situated at the extreme limits of the solar system, so far as was then known.

Q. What Appendages has Uranus attending it?

A. Uranus is attended with six moons.

Q. In what Direction do these Moons Move in their Orbits?

A. They revolve in an order contrary to the analogy of the whole solar system. Their orbits are nearly perpendicular to the ecliptic, advancing from east to west, while the other planets, with their satellites, move from west to east.

Q. Are these Satellites ever Eclipsed?

A. Proceeding from east to west, the second satellite, as shown in the Diagram, occasionally falls into the shadow of the planet, and suffers an eclipse. Yet eclipses are not of frequent occurrence in the system of Uranus.

Q. What are the Distances and Periodic Times of these Moons?

A. Their distance and periodic times are as follows:

| | Distance in Miles from the Primary. | Periodic Times. |
|---|---|---|
| 1st, | 240,000 | 5 days 21 hours. |
| 2d, | 296,000 | 8 " 11 " |
| 3d, | 340,000 | 10 " 23 " |
| 4th, | 390,000 | 13 " 11 " |
| 5th, | 777,000 | 38 " 2 " |
| 6th, | 1,555,000 | 117 " 17 " |

Q. What is the Eccentricity of the Orbit of Uranus?

A. About 85 millions of miles.

Q. When was the Planet Neptune Discovered?

A. In 1846.

## NEPTUNE.

Q. By Whom was Neptune Discovered?

A. By a French astronomer, Leverier, and also by a Mr. Adams, of Cambridge, England, who has put in his claim as the discoverer.

Q. What is the Place of this Planet in the Solar System?

A. So far as now known, it is placed at the extreme limits of the solar system.

Q. What is its Distance from the Sun?

A. Two thousand eight hundred and fifty millions of miles.

Q. What is its Diameter?

A. About the same as that of Uranus—35,000 miles.

Q. What is its Magnitude?

A. It is about 81 times as large as the earth.

Q. In what Time does it Revolve Around the Sun?

A. In about 164 years of our time.

Q. What is its Rate of Motion per Hour?

A. About 11,000 miles.

Q. Has it any Rings or Moons Attending it?

A. This planet is known to be attended by at least one satellite.

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## LESSON XXVIII.—The Moon.

Q. What is the Moon?

A. It is a secondary planet, revolving around the earth.

Q. Why is the Moon Called "a Secondary Planet?"

A. Because, it revolves around another planet, called a "primary planet." The primary planets revolve around the sun as their center of motion, while the secondary planets or moons, revolve around their primaries as their center of motion, and accompany them in their long journeys around the sun.

Q. What was the Design of God in Creating the Secondary Planets or Moons?

A. This design is apparent from the inspired statement of the purposes for which our moon was created. It is as follows: "And God said let there be lights in the firmament of heaven, to divide the day from the night; and let them be for signs and for seasons; and for days and for years; and let them be for lights in the firmament, to give light upon the earth; and it was so. And God made two great lights; the greater light to rule the day, and the lesser light to rule the night. And he made the stars also." Gen. 1, 14—16.

Q. How Many Moons have the Different Planets?

A. The Earth has one; Jupiter, four; Saturn, eight; Uranus, six; and Neptune, one; making twenty in all, so far as is positively known.

Q. Is the Moon Larger or Smaller than the Earth?

A. It is 49 times smaller.

Q. What is the Diameter of the Moon?

A. Two thousand one hundred and sixty miles.

Q. What is its Mean Distance from the Earth?

A. Two hundred and forty thousand miles.

Q. How Long does the Moon Require to make a Complete Revolution Around the Heavens?

A. Twenty-nine and a half days.

Q. What is this Revolution Through the Heavens called?

A. It is called the "moon's synodic revolution."

Q. In how Long a Time does the Moon Make a Revolution Around the Earth from one Fixed Star to the same Star again?

A. Twenty-seven days, 7 hours and 43 minutes?

Q. What is this Revolution Called?

A. It is called her "tropical or periodic revolution."

Q. What is the Cause of this Difference of about two Days between the Snyodic and Periodic or Tropical Revolution of the Moon?

A. This difference of time results from the onward motion of the earth in its orbit around the sun at the same time that the moon is performing her revolution around the earth. At new moon, the sun and moon are in the same part of the heavens; but by the time the moon has returned to that point, namely, 27 days, 7 hours, 43 minutes, the earth has proceeded in its orbit around the sun, 27 degrees farther to the east, and is still going on, and the moon has to undertake it before she can be again in that position which is called "new moon." [See the Diagram.]

Q. Does the Moon always Accompany the Earth?

A. The moon is the constant attendant of the earth from age to age, in all its long journey round the sun.

Q. Which Way does the Moon Revolve Around the Earth?

A. From west to east, as all of the bodies of the solar system do, except the satellites of Uranus.

Q. Why, then, Does the Moon Rise in the East?

A. Because, the earth revolves from west to east.

## LESSON XXIX.—The Moon—*Continued.*

### QUESTIONS ON THE CHART.

Q. How is the Moon Shown in the Diagram?

A. The moon is there shown in eight different positions, which it assumes in its orbit around the earth.

Q. What Are the Eight Different Positions?

A. "New moon," when she is directly between the earth and the sun; the "slender crescent," as she is seen on about the third day after the change; "half moon," as seen on the eighth day after the change; "gibbous phase," when more than one-half of her enlightened disc is turned to the earth; and after a few days more, her whole enlightened hemisphere is turned towards the earth, and she appears a "*full moon.*"

Q. How does She Appear After This?

A. She decreases, turning every day less and less of her enlightened hemisphere to the earth, exhibiting, in turn, the "gibbous phase," "half moon," "crescent," and then the "new moon," when she is in conjunction as before, and her dark side is turned to the earth, and she is invisible.

Q. In How Long a Time does She Pass Through these Changes?

A. In 29 days, 12 hours and 44 minutes, at an average, which is termed her "synodical revolution."

Q. Why does the Moon Show only a Crescent in Certain Points of her Orbit?

A. Because, her enlightened side is turned to the sun, and from our stand point on the earth, we can see only a small part of that enlightened surface.

Q. Why is She next Shown as a Half Moon?

A. Because, as she has advanced in her orbit, a larger portion of her enlightened hemisphere is turned towards the earth.

Q. Why does She Appear as Full when in Opposition to the Sun?

A. Because, in that part of her orbit, her whole enlightened hemisphere is turned to our view.

Q. How does She Appear After This?

A. Her enlightened disc gradually diminishes, exhibiting, in turn, a "gibbous face," "semi-circle," and "crescent," until she is finally lost sight of for a short time during the period of "new moon."

Q. Does the Moon Rise the Same Hour every Evening?

A. She rises about 50 minutes later every evening.

Q. Why does She Rise Later every Evening?

A. Because, she revolves round the earth from west to east.

Q. If the Moon Stood Still, would She Exhibit the Phases Shown in the Diagram?

A. She would not.

Q. When is it "New Moon?"

A. When the moon is between the earth and the sun, and her dark side is towards the earth and she is invisible.

Q. When is it "Full Moon?"

A. When the moon is upon the opposite side of the earth from the sun, and her enlightened side is turned towards the earth. [See Diagram.]

Q. What is the Appearance of the Moon when Viewed with a Telescope?

A. Its appearance is interesting and variegated. It seems like a map or model of another world, resembling in its prominent features, the earth. It is diversified with vales and mountains, and is covered with light and dark spots of various shapes.

Q. Has the Moon any Oceans, Seas or Large Bodies of Water?

A. This question has long engaged the attention of astronomers, without being settled. It is not clear that there are any large bodies of water on the side towards the earth, though it is not improbable that small lakes or rivers exist there. As we can see only one side of the moon, of course we know nothing of its opposite hemisphere.

Q. If you were Living on the Hemisphere of the Moon, towards the Earth, How would the Earth Appear?

A. Like a brilliant moon over our heads, suspended in empty space, stationary, and about 13 times larger than does the moon to us.

Q. What is the "Harvest Moon?"

A. It is the full moon in September and October, when it rises only a few minutes later for a number of successive evenings, and thus affords light for collecting the harvest.

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## LESSON XXX.—The Moon—*Continued.*

Q. Which is the Largest, the Moon or the Sun?

A. The sun is about 70 millions of times larger than the moon.

Q. Then Why do they Appear to be About the Same Size?

A. Because, the sun is 400 times farther from us than the moon. The sun is 95 millions of miles distant from us, while the moon is but about 240 thousand miles distant.

Q. When the Moon is in the Point of Her Orbit Nearest the Earth, where is She said to be?

A. In "perigee."

Q. When She is in the Point of Her Orbit Most Distant from the Earth, where is She said to be?

A. She is said to be in "apogee."

Q. What are these Two Opposite Sides of Her Orbit Called?

H. "The apsides of her orbit," and a line joining them is called "*the line of the apsides.*"

Q. Does the Moon Move in a Circular Orbit?

A. The orbits of all the planets, both primary and secondary, are more or less elliptical.

Q. When She Seems to Run Over and Obscure the Distant Planets and Stars, in Her Journey around the Earth, what is this Called?

A. This is called an "occulation."

Q. What is the Moon's Orbital Velocity, with respect to the Earth?

A. About 2,300 miles an hour.

Q. But, as She keeps up with the Earth Around the Sun, at the Same Time, What is Her Rate of Motion?

A. Not less than 70,300 miles an hour.

Q. What are the Extreme Points of the Crescent Shown in the Figure of the Moon, Called?

A. They are called the "cusps of the moon."

Q. What are the Two Points in Her Orbit Called, where She is Shown in the Diagram, as "New" and "Full Moon," 90 Degrees apart?

A. They are called her "syzigies."

Q. What are the Quadrations of the Moon?

A. They are four points in her orbit, 90 degrees apart, or a quarter of the circle of her orbit.

Q. What are Her "Octants?"

A. They are eight points in her orbit, as the eight places in the cut, where is shown in the Diagram.

Q. When the Moon Comes in Conjunction with the Sun, and is changed from "Old Moon" to "New Moon," what is She said to do?

A. She is said to "*change*."

Q. What is the Rocking or Rolling of the Moon in Her Orbit, Called?

A. It is called her "libration in longitude."

Q. What is the Rate of the Moon's Motion on its Axis, from West to East?

A. Only about 10 miles an hour.

Q When is the Velocity of the Moon in Her Orbit Greatest?

A. When she approaches the periods of "new" and "full moon."

Q. Has the Moon a Rotation on its Axis?

A. She has. She revolves on her axis in about 27½ days, or just the time in which she revolves around the earth.

Q. Do we Ever See More than One Hemisphere of the Moon?

A. We do not.

Q. Why do we Not See the Other Side of the Moon?

A. Because, she revolves on her axis in the same length of time that she revolves around the earth, which necessarily always keeps the same side towards us.

Q. Is there Any Difference Between the Length of a Lunar Day, Month and Year?

A. The length of time is the same; about 29½ days.

Q. What is a Lunation or Lunar Month?

A. It is the time from one new moon to another.

Q. What Motion has the Moon?

A. The moon must have a compound motion, since it revolves both around the sun and around its primary.

Q. To What Laws is the Moon Subject?

A. It is subject to the same law of gravitation, and of centripetal and centrifugal forces, as that of its primary, the earth.

Q. What Kind Office does it Afford the Earth?

A. It serves as a mirror, to reflect the light of the sun on the earth.

Q. What is the Eccentricity of its Orbit?

A. Thirteen thousand three hundred and thirty-three miles.

## LESSON XXXI.—Eclipses.

Q. What is an Eclipse?

A. An eclipse is a privation of the light of the sun, or of some other heavenly body, by the interposition of another body between it and our sight.

Q. How are Eclipses Divided, with respect to the body eclipsed?

A. Into solar and lunar. Eclipses are either of the sun or the moon, or of the satellites which accompany some of the planets.

Q. How are Eclipses Divided, in respect to circumstances?

A. They are divided into total, partial, annular, and central.

Q. What is a Total Eclipse?

A. When the whole face of the luminary is darkened.

Q. What is a Partial Eclipse?

A. When only a part of the disc is darkened.

Q. What is an Annular Eclipse?

A. It is when the whole is darkened except a ring or annualis, which appears round the dark part, like an illuminated border.

Q. What is a Solar Eclipse?

A. An eclipse of the sun.

Q. What Causes a Solar Eclipse?

A. The interposition of the body of the moon between the sun and the earth, when she throws a shadow over a certain portion of the earth.

Q. When Must an Eclipse of the Sun Take Place?

A. It can only happen at the time of the "new moon," and when the moon is at or near one of her nodes.

Q. Will you illustrate the Nature of a Solar Eclipse by the Diagram?

A. A solar eclipse is shown in the Diagram where the earth is represented in the month of July. The dark circle around the earth there represents the orbit of the moon; the circular figure in the circle, is the moon; and the cone or wedge extending to the earth, is the moon's shadow. The moon is in that part of its orbit next the sun, having its enlightened side towards the sun, and its dark side towards the earth, which is its position at "new moon." It is in its node, in an exact line between the sun and the earth. Here the shadow of the moon naturally falls upon a certain portion of the earth, and intercepts the rays of the sun for a little time from those portions of the earth on whom the shadow falls.

Q. Do we Have an Eclipse of the Sun at Every New Moon?

A. We do not; because at "new moon," the shadow generally falls above or below the earth.

Q. Why does the Moon's Shadow take the form of a Cone, as shown in the Figure?

A. Because, the moon is smaller than the sun.

Q. Does this Shadow Ever Come to a Point before Reaching the Earth?

A. It sometimes happens that the extremity of the cone of the moon's shadow falls short of the earth.

Q. What Will this Produce?

A. An annual eclipse of the sun; in which case the

sun appears like a brilliant ring of light around the dark body of the moon.

Q. What is the Length of the Moon's Shadow?

A. Two hundred and thirty-four thousand miles—6,000 miles less than the mean distance of the moon from the earth, and hence it will frequently fail to reach the earth.

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## LESSON XXXII.—Eclipses—*Continued.*

Q. Why Are Not all Eclipses of the Sun Total?

A. Because, the moon, being so small, compared with the sun, and being so far from the earth, its shadow, in accordance with the laws of shadows, terminates in a point before it reaches the earth. In order to a total eclipse, the moon must be in its perigee or nearest to the earth.

Q. How Long May a Total Eclipse of the Sun Continue at any one Place on the Earth?

A. Not over four minutes.

Q. How is an Eclipse of the Moon Produced?

A. By an interposition of the earth between the sun and the moon.

Q. When Can an Eclipse of the Moon Take Place?

A. Only at "full moon," when the moon is in opposition to the sun. [See the Diagram, where the earth is shown in the month of January.]

Q. Why Does the Earth Cast a shadow, as there shown, in a Direction Opposite to the Sun?

A. Because she is an opaque body, and enlightened by the sun.

Q. How Far will this Cone or Shadow of the Earth Reach before Terminating in a Point?

A. About 840 thousand miles.

Q. Why Does Not the Moon Suffer a Total Eclipse at the Time of Every Full Moon?

A. Because, she does not always move in the plane of the ecliptic, so as to pass through the center of the earth's shadow.

Q. How Many Eclipses may Take Place in a Year?

A. Seven; five of the sun and two of the moon. Two is the smallest number that can happen, and both must be of the sun.

Q. Why are there More Eclipses of the Sun than of the Moon?

A. Because the solar ecliptic limit is far greater than that of the moon.

Q. What is a "Digit?"

A. It is the twelfth part of the apparent diameter of the sun or moon's disc.

Q. Are Visible Eclipses of the Moon More Frequent, at any Particular Place, than those of the Sun?

A. They are.

Q. Why are they?

A. Because, an eclipse of the moon is visible, and appears as great to all places on the earth where the moon is above the horizon.

Q. Where does an Eclipse of the Moon Begin?

A. An eclipse of the moon always begins on the moon's eastern side, and goes off on her western side.

Q. How Far are Eclipses of the Moon Visible?

A. In all parts of the world, where the moon is above the horizon; and are everywhere of the same magnitude and duration.

Q. How is the Moon's Diameter Divided?

A. It is supposed to be divided into twelve equal parts, called "digits," and as many of these parts as are darkened by the earth's shadow, so many digits is the moon said to be eclipsed.

Q. Is the Moon Invisible when Totally Eclipsed?

A. She is not, if she is above the horizon, and the atmosphere is clear.

Q. How does the Moon Appear when Eclipsed?

A. Generally of a dusky color, somewhat like tarnished copper, especially towards the edges, being generally more dark about the middle of the earth's shadow.

Q. Is the Moon *Always* Visible During a Lunar Eclipse?

A. It is not.

Q. What is Meant by the "Umbra" of the Moon, Earth, or any of the Planets?

A. It is the total dark shadow of the planet.

Q. What is the "Penumbra?"

A. It is a faint shadow surrounding the umbra.

Q. What is the Greatest Extent of the Moon's Umbra upon the Earth?

A. One hundred and seventy-five miles.

## LESSON XXXIII.—Eclipses—*Continued.*

Q. Where do Eclipses of the Sun Begin?

A. They always begin on its western side. It will be seen from the Chart, in the Diagram of a solar eclipse, that the eclipses of the sun necessarily come from the *west*, and pass over eastward. The reason of this is very obvious, since the moon passes from west to east, between the earth and sun.

Q. Why do Eclipses of the Moon Begin on her Eastern Side?

A. Because, the moon passes from west to east, through the earth's shadow.

Q. In what Direction does the Moon's Shadow Pass Over the Earth in a Solar Eclipse?

A. As shown in the Diagram, it passes over the earth from west to east.

Q. What is the Duration of a Central Eclipse of the Moon, when the Moon is at her Greatest Distance from the Earth?

A. Three hours, fifty-seven minutes, twenty-six seconds, from beginning to end.

Q. What is the Duration of a Central Eclipse of the Moon, when She is at her Least Distance from the Earth?

A. Three hours, thirty-seven minutes, twenty-six seconds.

Q. Can the Moon be Totally Eclipsed Without Passing Through the Center of the Earth's Shadow?

A. She can.

Q. How Large a Portion of the Earth's Surface may be Covered by the Moon's Penumbra?

A. A space of about 4,393 miles in diameter.

Q. Will you Explain from the Diagram, the Philosophy of a Lunar Eclipse?

A. The nature and cause of eclipses will readily be understood by an inspection of the Chart. A lunar eclipse is there shown, in connection with the earth, when at the place in her orbit designated as "January." The earth is there shown as casting a shadow from it in the form of a cone. All the planets, both primaries and secondaries, cast shadows in a direction opposite to the sun. The sun being larger than the earth, the shadow will take the form of a cone, as shown in the figure, and will end at a point at the distance of about 840,000 miles from the earth. The dark circular figure seen there, in the earth's shadow, and in the circle surrounding the earth, represents the moon; and the circle itself, the orbit of the moon. The moon is then in opposition to the sun, and is passing through the earth's shadow. As the earth is about 8,000 miles in diameter, its shadow near its surface, must be about 8,000 miles broad. But as the shadow of the earth takes the form of a cone, and as the moon is about 240,000 miles from the earth, the earth's shadow at that distance, will be about 6,000 miles broad; and, as the moon is only 2,160 miles in diameter, she must be completely immersed in the shadow of the earth, and must move nearly three times her whole diameter before she can emerge from the shadow.

Q. Are Eclipses Matters of any Considerable Importance to Mankind?

A. Eclipses constitute some of the most grand and sublime phenomena of the heavens.

## LESSON XXXIV.—Comets.

Q. What other Bodies, Besides the Sun, Planets and their Satellites, Belong to the Solar System?

A. Another singular class, called "comets." The course of comets will be better understood by turning your attention to the right hand on the Chart, where one is shown as flying across the orbits of the planets, and advancing near the sun, and then departing.

Q. How do these Singular Bodies Appear?

A. They gradually come into view, increasing in brightness and velocity until they attain a maximum, where they remain for a time, then as gradually diminish, pass off, and are lost in the distance.

Q. Are Comets Solid Bodies, Like the Planets?

A. Our knowledge of these bodies is very limited, and no decisive opinions of them can safely be pretended.

Q. What is the Meaning of the Word "Comet?"

A. This word literally signifies a *hairy star*, because comets are generally accompanied with a nebulous appearance or train, which has the resemblance of luminous hair.

Q. What is the Nucleus of a Comet?

A. The luminous point near the center, which is the most brilliant.

Q. What is the Hair or Envelope of a Comet?

A. The haze or nebulosity which surrounds the nucleus.

Q. What is called the Tail of a Comet?

A. The luminous train, which sometimes extends to a great distance from the head, is the tail of the comet.

Q. Was the Existence of Comets Known to the Ancients?

A. It was. Comets have occasionally appeared in the heavens in all ages.

Q. What is the Direction of the Luminous Tail of Comets?

A. Usually on the opposite side from the sun; but a few have been observed to have a different direction.

Q. What are Comets now Supposed to be?

A. Since the days of Sir Isaac Newton, they have been considered as bodies constituting parts of the solar system, and that their motions are performed in long eclipses, having the sun in one of their foci.

Q. Do Comets Always Appear Attended with the Appendage of a Luminous Train?

A. Some have appeared without such an appendage.

Q. Do Comets all, like the Planets, Revolve in the Same Direction Round the Sun?

A. They do not. They come plunging from all points, down into the solar system, and pass round the sun, and then take their departure in greatly elongated orbits, as shown in the Diagram.

Q. Are the Orbits of all the Comets Within the Limits of the Zodiac?

A. They are not. They are in all parts of the heavens.

Q. What is the Appearance of the Comet, as it Recedes from the Sun?

A. It is a remarkable fact, that the real diameter of its nebulosity increases proportionally as the comet becomes distant from the sun. This remarkable circumstance has

been attempted to be accounted for, but no satisfactory hypothesis has yet been reached.

Q. What is the Form of the Orbits of Comets?

A. They are extremely eccentric, and form very elongated ellipses.

Q. What is the Periodic Time of Comets?

A. Many Comets are supposed to have periods of a thousand years.

Q. To what Distance do they Go from the Sun?

A. It must be very great, since they are absent so long from our system.

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## LESSON XXXV.

I have now given a brief description of all the planets, satellites and comets of the solar system, with the sun as the central and controlling force, that retains them in their orbits from age to age.

The harmony, order, simplicity and wisdom, displayed in the structure of the solar system, will be better appreciated by a minute inspection of the Chart, where the planets are all seen in their proper places, attended by their respective moons, and all revolving with great rapidity in their orbits—the primaries around the sun, and the secondaries around their respective primaries. Meantime all are in swift rotation on their axis, thus turning their different sides alternately to and from the sun, and securing the indispensably important and agreeable vicissitudes of day and night, and change of seasons, proportioned to

the inclination of their axis. The sun is seen as placed in the center, which is the most feasible point from which to send out incessant streams of light and heat to all this vast family of distant and revolving worlds.

## GRAVITATION.

Q. What is "Gravitation?"

A. It is the act of tending to the center, or of being drawn towards something—the tendency of all matter in the universe towards all other matter. Every portion or body of matter attracts and is attracted, directly as its quantity of matter, and inversely, as the square of its distance from the attracting body.

Q. Is this the Binding Force that Holds all the Heavenly Bodies in their Appropriate Places?

A. It is.

Q. Will you more Fully Illustrate and Explain the Principles of Gravitation?

A. When one body revolves around another as its center of motion, it is influenced by two forces: one of which tends to make it fly off from the central body, and the other to approach it.

Q. What are these two Principles Called that thus Operate upon the Flying Body?

A. They are called "centrifugal" and "centripetal" forces.

Q. What is the Nature of the Centrifugal Force?

A. It tends to make a body fly off from the central body.

Q. What is the Centripetal Force?

A. It is that force or principle that impels the flying body to *approach* the central body.

Q. Will you Illustrate the Practical Operations of these two Opposite and Contending Principles or Forces?

A. When a boy fastens a stone to one end of a string, and holding the other in his hand, whirls the stone around, it describes a path or orbit under the action or influence of centrifugal and centripetal forces.

Q. Suppose that while the stone is in rapid motion, the string should be suddenly cut, would it continue, to revolve in a circle?

A. It would not. It would quickly fly away from the hand, the center of its orbit.

Q. What Force or Principle Makes it Fly Off?

A. Its centrifugal force. When the string was whole the stone was prevented from obeying the centrifugal force, and was kept in a circular path by the resistance of the centripetal force—the string in the boy's hand, which actually drew it towards the center of its orbit, with a power that just balanced the centrifugal force that would drive it off in a straight line. The power of the string is therefore the centripetal force.

Q. In the light of these definitions and this illustration, can you not More Fully Illustrate the Principle of Attraction?

A. We will suppose that a power of attraction resides in the boy's hand, which draws the stone towards him, instead of a material bond, as a string, just as a magnet draws to itself any particles of iron that may be near it. This is the principle on which the power of attraction

works. The attractive power (centripetal force,) is so nicely adjusted to the centripetal force or the force that drives off the stone in a straight line, when free, that one force just counterbalances the other, and the stone is made to describe a circular path.

Q. Is this the Principle on which the Planets and Satellites are made to Revolve in their Orbits around the Sun?

A. It is. A heavenly body revolves about the central orb under the action of centrifugal and centripetal forces; but it is not bound to its central orb by any material bond, as a cord or chain. There actually resides in the central body, an attracting force, which constitutes the centripetal power, and balances the centrifugal force, or tendency to fly off.

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## LESSON XXXVI.—Gravitation—*Continued.*

Can you give any other Example of the Operations of the Force of Gravity?

A. When an apple falls from a tree, it descends in a straight line towards the center of the earth, under the influence of what is termed the force of gravity. There must, therefore, reside in the earth a power which tends to draw the apple towards its center. This power is the centripetal force illustrated more fully in another lesson.

Q. Can you give another Illustration of the Workings of the Forces Described.

A. When a cannon ball is fired into the air, it does not continue its course in a straight line, as it would if influ-

enced only by a projectile force; but it describes a curved line under the influence of the force of gravity, and is finally drawn to the earth.

Q. On what Circumstance will the Extent of Surface passed over by the Projected Body, depend?

A. On the greatness of the projectile force; and if the projectile force be sufficiently great, it is reasonable to suppose that the projected body might be carried completely round the earth to the point whence it started. And should the projectile force remain the same, with no abatement, the projected body would continue its circuit from age to age, like the moon.

Q. Does this law of Gravitation Pervade all Matter?

A. This is a universal law, extending to all matter in the universe. It is this law of gravitation that retains all the planets in their orbits. The Omnipotent and All-wise God has made the sun of such determinate size, and placed it at just the proper distance from the planets, and so nicely adjusted their density and motions to this great central and controlling force, that when the planets are once launched into space, the centrifugal force with which they are thrown forward in a straight course, is happily counterbalanced by the centripetal force—the sun's attraction—that it is drawn into a curved line, and made to describe the circle, delineated on the Diagram, as the form of a planetary orbit.

## LESSON XXXVII.

### HOW TO FIND THE CIRCUMFERENCE OF THE EARTH.

Q. How is it Known that the Diameter of the Earth is about 8,000 miles, and its Circumference 25,000?

A. It is determined as follows: "All circles, great or small, are supposed to be divided into 360 equal parts, called degrees. From this it is seen that a degree has no definite measure; but depends upon the magnitude of the circle. If we suppose a circle to be 360 miles in circumference, then one degree would measure just one mile; but if the circle were greater, a degree would be greater, and if less, a degree would be less. We will now apply this principle of the circle to measure the circumference of the earth. In order to do this, we must take two places some distance apart, and under the same meridian; for example, New York and Albany. We will suppose that the distance between the two places has been found, by exact measurement, to be 138½ miles. (This distance, probably, does not vary much from the truth.) We will now place an observer at each point, with accurate instruments, and on a particular night, at 12 o'clock, the observer at New York finds a particular star exactly in his zenith, or over his head; but the observer at Albany finds the same star two degrees to the south of his zenith. Hence, it will be seen that there are two degrees between the two places; and as the distance, by measurement, was found to be 138½ miles, the two degrees between New York and Albany, are equal to 138½ miles, or one degree equals 69¼ miles. Now, if we multiply the number of

degrees in the whole circumference of the earth, (360) by 69¼ miles, it will give 24,930 miles as the whole circumference of the earth."—*Smith's Illustrated Astronomy.*

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## LESSON XXXVIII.

### HOW TO FIND THE DISTANCES OF THE PLANETS FROM THE SUN.

Q. How can the Distance of a Planet from the Sun be Found?

A. By one of the three great laws discovered by the celebrated astronomer, Kepler, viz: All the planets are subject to one general law, which is, that the "squares of their periodic times are proportional to the cubes of their mean distances from the sun."

Q. Do Astronomers Recognize the Validity of this law?

A. They do. This law was more fully unfolded and demonstrated by Sir Isaac Newton.

Q. How did Astronomers find the Periodic Times of the Planets?

A. By observing the time it took each planet to revolve around the sun from any particular star to the same star again.

Q. Did Astronomers Find it as Easy to Determine the Distance of a Planet from the Sun, as they did its Periodic Time?

A. They did not. They found the task very difficult.

Q. How was the Distance of the Earth from the Sun Found?

A. It was found by observations made upon the transits of Venus. Calculations based upon this data, determined the distance of the earth from the sun, to be about 95 millions of miles.

Q. But How Can the Distance of the Planets be Determined from any such Circumstances?

A. As we have the periodic times of the planets, and have the distance of one of them from the sun, by this law of Kepler's, we can find the distance of the other planets by the simple rule of proportion.

Q. Will you Make an Application of this Rule, in Determining the Distance of Mercury from the Sun?

A. To do this, we say, as the square of 365 days (which is 133,225,) is to the cube of 95,000,000 of miles (which is 857,375,000,000,000,000,000,000,) so is the square of 88 days (which is 7,744) to a fourth term, which is the cube of Mercury's distance from the sun. And when the cube root of this term is extracted, the answer is found to be 37,000,000 of miles, nearly.

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## LESSON XXXIX.

### HOW TO FIND THE MAGNITUDES OF THE PLANETS.

Q. By what Rule do Astronomers Determine the Magnitude of the Planets?

A. It has been found that the magnitudes of all globes or spheres, are in proportion to one another, as the cubes of their diameters. Hence, if we cube the diameters of any two globes, and divide the greater product by the less, the quotient will show how many times the one is greater than the other.

Q. What is the Cube of any Number?

A. It is the number multiplied into itself, and that product multiplied by the first number.

Q. Will you Give an Example of the Cube, &c.?

A. Take two globes, one of five feet, and the other ten feet in diameter:

| | |
|---|---|
| 5 | 10 |
| 5 | 10 |
| 25 | 100 |
| 5 | 10 |
| 125 cube of 5. | 1000 cube of 10. |

Then $125 \left\{ \begin{matrix} \\ 1000 \end{matrix} \right. \div \left\{ \begin{matrix} 1000 \\ \\ \end{matrix} \right. = 8$

Hence it is manifest that the globe of ten feet in diameter is eight times the magnitude of a globe five feet in diameter.

Q. How Large would the Sun appear if Shown in its Relative Magnitude to the Planets?

A. It would more than fill up all the space on the Chart within the orbit of Jupiter.

Q. Where are the Comparative Distances of the Planets Shown?

A. At the lower side of the Chart, the scale is shown between the orbits of Uranus and Neptune. The perpendicular lines indicate the respective distances of the planets from the sun and from each other. S, designates the sun; M, Mercury; V, Venus; E, the Earth; A, the Asteroids; J, Jupiter; S, Saturn; U, Uranus; and N, Neptune.

# TESTIMONIALS OF COMMENDATION

TO

## EMMONS' CHART OF THE SOLAR SYSTEM.

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STATE OF NEW YORK,
Superintendent's Office, Dep't Public Instruction,
Albany, January 30, 1860.

WILLIAM EMMONS, ESQ.—Dear Sir: I regard your Chart of the Solar System, as admirably adapted to enlist the attention of Scholars, and to impart an accurate knowledge of the relative position and movements of the heavenly bodies. I trust you may be successful in securing its introduction into the Schools, where it must prove a useful auxiliary in promoting Astronomical Studies.

I have the honor to remain,

Your obedient servant,

H. H. VAN DYCKE.
Sup't Pub. Instruction.

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STATE OF PENNSYLVANIA,
Department of Common Schools,
Harrisburg, Jan. 28, 1864.

MR. WILLIAM EMMONS—Dear Sir: I have examined as carefully as my limited time would allow, the Chart of the Solar System prepared by yourself. It appears to be accurate, and it presents the whole subject to the eye at one view, in so compact a form, that it can but be instructive and interesting to those who desire to gain a knowledge of the position, size, orbits, velocities, and the various phenomena of the bodies that compose our system. I recommend its introduction to the directors of the several Schools in this Commonwealth.

C. R. COBURN.

We entirely concur with others in commending "Emmons' Chart," as a valuable piece of Apparatus for Schools and Families.

DANIEL READ,
E. S. CARR,
University of Wisconsin.

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I fully agree with Professors Read and Carr, of the State University of Wisconsin, in their commendation of "Emmons' Astronomical Chart," and believe it worthy of general patronage.

DANIEL DRAKE,
State Sup't of Public Instruction.

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OBERLIN, Ohio, Nov., 1860.

DEAR SIR—I have examined "Emmons' Astronomical Chart." I have no hesitation in recommending its general introduction into the Schools of our country. It will do much to give the young a correct impression of the Solar System, and will afford invaluable aid to the Teacher.

Yours truly,

C. H. CHURCHILL,
Prof. of Math. & Nat. Philos. & Teacher of Astronomy,
Oberlin College.

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GENESEE COLLEGE, Lima, N. Y.

I have examined the Chart of Mr. Emmons, and would commend it to Teachers, as a valuable aid in teaching Astronomy.

JOHN MORRISON REED,
President of Genesee College.

We concur in the above.

WM. HOPKINS,
WM. WELLS,
E. E. E. BRAGDON,
Profs. in Genesee College.

MR. WM. EMMONS—Sir: I have examined your Chart of the Solar System. * * * * I cheerfully recommend it as worthy of a place and attention in every school.

VICTOR M. RICE,

Late Supt. of Pub. Inst., State of New York.

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STATE OF INDIANA,
Department of Public Instruction,
Office of the Superintendent, Feb. 11, 1861.

MR. WILLIAM EMMONS—Dear Sir: I am glad to learn that you are making an effort to introduce into the Schools of the State, your Chart of the Solar System, as an article of School furniture. The effect of its instruction will be, to furnish the children at an early age, a pretty good idea of the shape, proportion and movements of the Astronomical Bodies. It will also induce in children a taste for the study of the Science of Astronomy, which they will be likely to pursue, more or less, in a more mature life. I advise all Township Trustees and School Teachers of Towns and Cities, to add it to their list of School furniture as soon as the means of their doing so will justify.

With much respect,
Your obedient servant,

SAMUEL L. RUGG,
Superintendent of Public Instruction.

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