THE

YOUNG ASTRONOMER.

DESIGNED FOR

COMMON SCHOOLS.

ILLUSTRATED BY CUTS.

BY SAMUEL WORCESTER.

BOSTON:
CARTER, HENDEE, AND CO.
1833.

EPHRAIM W. MORSE,

NEWBURYPORT.

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REMARKS TO TEACHERS.

We do not give to children the abstract, philosophical principles of the several sciences. They are first taught the most interesting and useful facts belonging to each science; and, as their minds become more perfectly formed, we introduce the more abstruse phenomena and principles. The science of Astronomy seems not, however, to have been so far divested of its more difficult parts, as to be adapted to our Common Schools; and, therefore, our children grow up in ignorance of much valuable truth relating to this subject, which they are capable of receiving.

It may be of use to Teachers, to remark that the author designed this little work for those children, who have once properly studied their larger Geography. It is believed that all such children will be found capable of understanding so much of Astronomy as is treated of in this book; and it will assist them in understanding many parts of Geography. After studying this work, they may review the two sciences separately, or in connexion with each other, as may be found most convenient.

Although this work is particularly designed for schools, and is therefore a book for study rather than simple reading, yet, those who have not leisure to study it regularly, may derive from it much information. And it is recommended that even persons of this class should pay particular attention to the questions at the end of each paragraph. They will thereby be greatly assisted in understanding what are the leading, practical truths, which the author designed to teach.

The mode of questioning here presented is thought to be well adapted, to make the scholar learn his lessons thoroughly, and to be well suited to this science. The teacher will find it useful, to add many other questions and examples; but each part of a lesson should receive its proper share of attention, and caution should be used, that leading facts and principles be not lost in a display of minor facts and circumstances.

ASTRONOMY

INTRODUCTORY CHAPTER.

1. Astronomy treats of the Sun, Moon, Planets, Stars, and other heavenly bodies. Before you can well understand what we have to say about these wonderful things, you must learn the meaning of a few words that we shall often use. You must also have a ball, with a hole through its middle, and a stick in it. An apple or an orange will answer the purpose, but a wooden ball will be better.

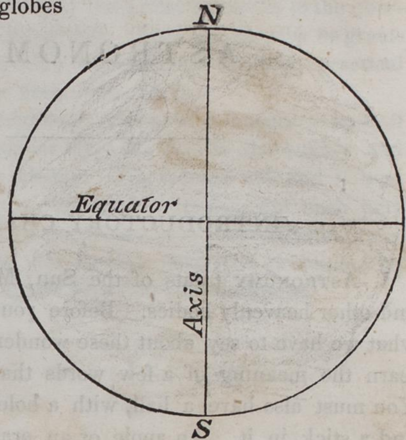
What does Astronomy treat of?

2. Your ball is a *globe* or *sphere*. Everything, whether great or small, that is shaped like a ball, is called a *globe* or *sphere*. An apple, an orange, this great Earth on which we live, the Moon, the Planets, and the Sun are all shaped in nearly the same manner, and we therefore say that they are *globular* or *spherical*.

What is a globe? Mention several *spheres*, both large and small.

3. We cannot make a good picture of a ball on paper, but

this figure will help to explain some things respecting your wooden ball, and all other globes



4. The *axis* of a globe is a line passing through its centre, as the hole or stick goes through your ball; and when the globe turns round, it turns on its *axis*.

5. Mark N. and S. on the ball as they are marked in the picture, and hold it so that N. will point to the North, and S. to the South; and call those parts of the ball the North Pole and the South Pole.

What is the end of the axis called, which points to the north? What is the opposite end called?

6. The *equator* is a line surrounding a globe at an equal distance from each pole. Make a mark with a piece of chalk, or pass a string round your ball in this manner, and it will represent its equator. The term *equator* commonly denotes a line round the globe on which we live, at equal distances from the North Pole and the South Pole.

What is the *equator*?

7. The *diameter* of a globe is any straight line passing through the middle of it, as the stick runs through the ball. So, also, any straight line passing through the centre of a circle, from one side to the other, is its *diameter*.

What is the *diameter* of a globe or a circle?

8. The *circumference* of a globe is the distance around it in the middle. Thus the equator measures the circumference; and a line passing round the middle in any other direction, will do the same.

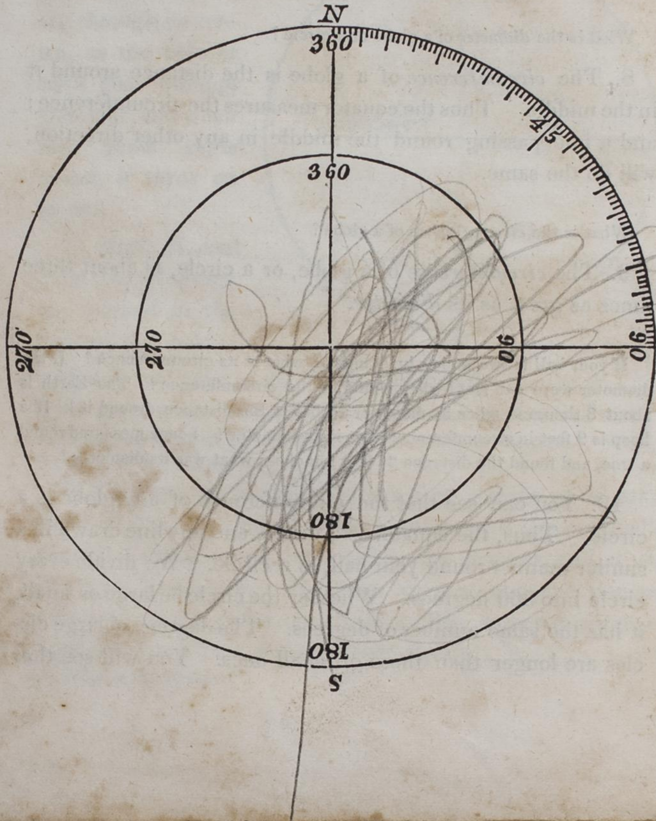
What is the *circumference* of a globe?

9. The *circumference* of a globe, or a circle, is about three times as great as its *diameter*.

If your ball is two inches in diameter, what is its circumference? If the diameter were one foot, what would be the circumference? The Earth is about 8 thousand miles in diameter; what is the distance around it? If a hoop is 9 feet in circumference, what is its diameter? I once measured round a tree, and found the distance 24 feet 9 inches; what was its diameter?

10. You can see that the circumference of any globe is a circle. Thus, the equator is a circle, and any line drawn in a similar manner round your ball, is a circle. We divide every circle into 360 degrees. Whether the circle be large or small, it has the same number of degrees. The degrees of large circles are longer than those of small ones. You will see that

a part of this large circle is divided into single degrees; and both circles are divided into halves and quarters. A quarter of a circle is 90 degrees: it is sometimes called a *quadrant*. A half of a circle is 180 degrees: it is often called a *semicircle*.



How many degrees are there in a circle? How many degrees make a quadrant? How many make a semicircle? Are the degrees of all circles of the same length?

11. Degrees are sometimes divided into equal parts, called minutes; and minutes into equal parts, called seconds. *Sixty seconds* make a minute, and *sixty minutes* a degree. Degrees are marked with a small cipher; minutes with a small accent; and seconds with a double accent. Thus, 10° 12′ 11″ are ten degrees, twelve minutes, and eleven seconds.

How many seconds make a minute? How many minutes a degree? How many degrees a circle? Read these figures, 20° 14′ 17″. Read these, 140° 23′ 39″.

12. A *telescope* is an instrument for looking at the sun, moon, planets, and other distant objects. It causes distant objects to appear nearer. There are several kinds of telescopes, but they are all fitted with such glasses, as make distant objects appear larger and nearer, and thus enable us to see them better.

What is the use of a telescope?

CHAPTER I.

THE SUN, ☉.

1. The Sun is a great globe: it is much larger than anything else that we know. When we look at it without a telescope, it does not appear to be more than one or two feet in diameter; but the best telescopes make it appear very much larger. Astronomers have discovered several methods of ascertaining its size; and they find its diameter to be more than 860 thousand miles. The Sun is more than a million times larger than this earth.

What is the shape of the Sun? How great is its diameter? What do you mean by the diameter of a globe? How much larger is the Sun than the earth?

2. The Sun appears small, because it is so far from us. You know that all things appear smaller when distant, than when near you. A house can hardly be seen ten miles; and a little fly that is quite near you, appears larger than an ox that is a mile off. The Sun is about 95 millions of miles from the earth. If a bird could fly towards it, at the rate of two miles every minute, it would require about ninety years to reach the Sun.

Why does the Sun appear so small? How far are we from the Sun? How long would it take a pigeon, flying two miles every minute, to reach the Sun?

3. The Sun gives us light and heat, and you can easily understand that nothing in this world could live without it It should remind us of the Lord, who is called the Sun of Righteousness. His truth is the light of our minds, and His love gives life to our souls.

What do we receive from the Sun? Of whom should the Sun remind us?

4. The Sun *appears* to move round the earth every day, but this is not really the fact. We shall explain this subject in another chapter. The Sun does, however, turn round on its own axis once in twenty-five and a half days.

Does the Sun revolve round the earth? In what time does it revolve on its own axis?

Turn your ball round upon the stick that runs through it, and you will see how the Sun turns on its axis.

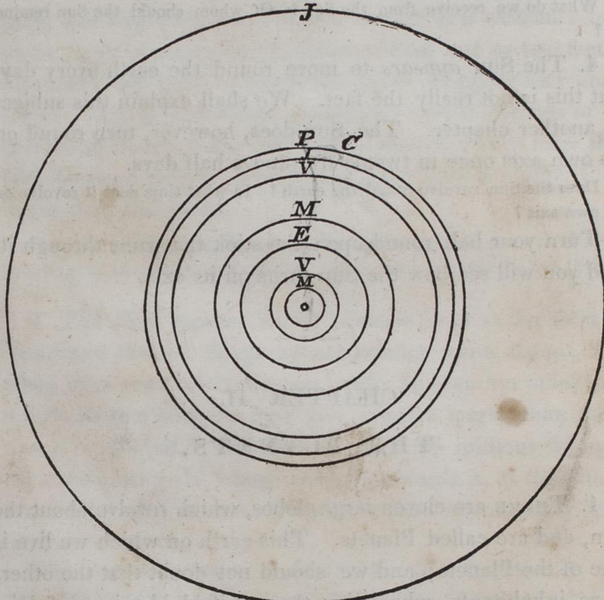
CHAPTER II.

THE PLANETS.

1. There are eleven large globes, which revolve about the sun, and are called Planets. This earth on which we live is one of the Planets; and we should not doubt that the others have inhabitants, who enjoy the manifold blessings of Him who is Lord over all

How many Planets are there? What is their shape? Do the Planets revolve round the sun, or does the sun revolve round the Planets?

2. The names of the Planets are Mercury, Venus, the Earth, Mars, Vesta, Juno, Pallas, Ceres, Jupiter, Saturn, and Uranus or Herschel. Mercury is the nearest to the sun, and



you will see the comparative distances of all, except Saturn and Uranus, in this figure. These two are so much farther than Jupiter, that there is not room here to represent their distances. Pallas and Ceres are so nearly at an equal distance, that one circle is marked for both.

What are the names of the Planets? How many are nearer the sun than the earth is?

3. The line or path in which a Planet goes round the sun, is called its *orbit*. When a Planet is going round the sun, it does not keep at the same distance all the time; but is sometimes nearer the sun than at others. Hence its orbit is not a circle; it is an ellipse. You will see the difference between a circle and an oval or ellipse by these figures.

Circle.

Ellipse.

What is the *orbit* of a Planet? What is the shape of the orbits of the Planets? Is a Planet always equally distant from the sun?

4. The time in which a Planet goes round the sun, is called its *year*. You know that a year on this earth is 365¼ days. It is 365 days when it is not leap-year, and 366 days when it is leap-year and leap-year comes once in four years. Some of the Planets have much longer years, but Mercury and Venus have shorter.

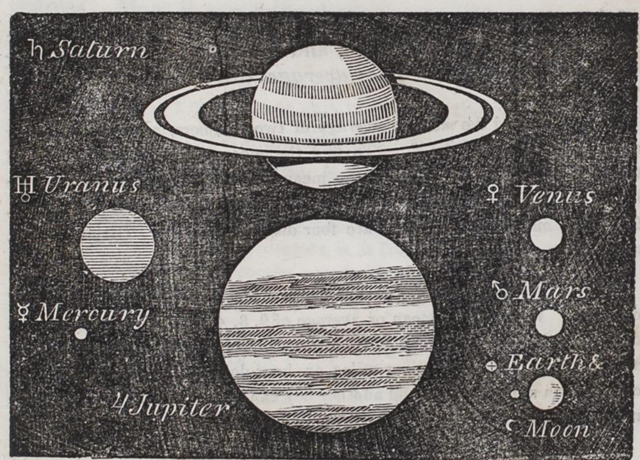
What is a *year*? How long is a year on this earth? How many days is the year in leap-year? Have any of the Planets longer years? Have any of them shorter years?

5. The time in which a Planet revolves once on its own axis is a *day*. We begin our day at midnight, and divide it into 24 hours. Most of the Planets revolve in much less time than the earth does, and therefore have shorter days.

What is a *day*? At what time do we begin our day? Into how many hours is it divided? Are the days on the other Planets just as long as ours?

6. We said that the Planets are not all of the same size. This picture will show the comparative size of most of them: the others are too small to be well compared in a picture. The marks, placed before the names of the Planets, are those which are often used instead of the names in Almanacs and books of Astronomy.

Which Planet is the largest? Which has a great ring round it? How many of the Planets are larger than the earth?



7. Several of the Planets are frequently seen by us in clear evenings. They give a more steady, or less twinkling light, than the stars; but most persons do not observe the difference.

Are any of the Planets ever seen by us? How do they appear?

CHAPTER III.

MERCURY, ☿.

1. We shall now give a more particular account of each of the planets. Mercury is much nearer to the sun than either

of the others. Its mean distance is about 37 millions of miles. It is sometimes a little more, and sometimes a little less distant; but this is its *mean* or *average* distance.

Note. To find the *mean* or *average* of two numbers, add them together and divide their sum by 2. To find the mean of three numbers, add them, and divide by 3. To find the mean of fifty numbers, add, and divide by 50. The same rule applies to all cases. Thus, find the mean of 4, 5, 6, 9. These make 24; and there are four distinct numbers. Divide 24 by 4, and the answer is 6.

Which planet is nearest the sun? How far is it? Is it always just 37 millions? What is the mean or average of 9, 8, 4, 11? If you walk a part of a day at 2 miles an hour, an equal part at 3 miles an hour, and an equal part at 4 miles an hour, how many miles an hour does it average? If one boy can throw a stone 10 rods, and another boy can throw it 20 rods, what is the mean distance?

2. Mercury revolves on its axis from west to east once in 24 hours, and revolves round the sun in about 88 days.

How long is a day at Mercury? How long is a year? How many of our months are there in a year of Mercury? How many seasons have we? If Mercury has four seasons, how long is each?

3. Mercury never appears far from the sun. It is commonly so near, that the brightness of the sun prevents our seeing it; but it is sometimes visible a little after sunset. The apparent distance of a planet from the sun is called its *elongation*. Try now to understand this. Point your finger towards the east. Now move it over slowly till it points to the west. It has moved just half a circle, and that is 180

degrees. Move it now from the horizon to the zenith or the point directly overhead. That is a quarter of a circle or 90 degrees. Half of the distance from the horizon to the zenith is 45 degrees. You will see this plainly by the figure on p. 8 Mercury never appears more than 28 degrees from the sun; that is, its greatest elongation is 28°

Is Mercury often seen? Why is it seldom visible? What is the *elongation* of a planet? How many degrees is it from east to west, or from any part of the horizon to the opposite part? How far from the horizon to the zenith? What is half that distance? What is the greatest elongation of Mercury?

4. The sun appears to move round the earth once in 24 hours. The whole distance that it appears to go, is a circle.

How many degrees make a circle? How many degrees does the sun appear to move in 24 hours? How many in one hour? How many in two hours? How many hours does it take for the sun to appear to move 90 degrees? When the days from sunrise to sunset are twelve hours long, how many degrees does the sun appear to move in the day?

Remember that the apparent motion of the sun and stars, is 15 degrees an hour.

5. Mercury is a small planet; it is about one fifteenth part as large as this earth. Its diameter is about 3000 miles.

Is Mercury as large as this earth? What is its diameter? Recollect how much more the circumference of a globe or circle is, than its diameter; and then find the circumference of Mercury.

6. Mercury is so much nearer the sun than this earth is, that the climate is probably warmer; but we do not know that it is so much warmer and lighter, as it is nearer the sun.

Is there probably more heat and light at Mereury, than we have ?

CHAPTER IV.

VENUS. ♀.

1. Venus is the most beautiful of all the planets that we can see. Its light is very white and pleasant We see it very frequently for several hours in the evening, or early in the morning. Its greatest elongation, or apparent distance from the sun, is 47°.

What is the appearance of Venus ? Can we often see it ? How many hours high does Venus ever appear after the sun sets ? How many hours does it sometimes rise before the sun ? *The number of hours that it sets after the sun, or rises before the sun, is found by seeing how many times 15 degrees there are in 47°.*

2. Venus is almost as large as the earth. Its mean distance from the sun is 68 millions of miles: it revolves on its axis from west to east in a little less than 24 hours; and revolves round the sun in $7\frac{1}{2}$ of our months.

How large is Venus ? What is its mean distance from the sun ? How long is a day at Venus ? How long is a year ?

3. When Venus is seen through a telescope it appears very differently from what it does to the naked eye. We do not see the whole of that half of it on which the sun shines, and therefore it does not appear round. You know how differently the moon appears at different times; and Venus and Mercury have similar appearances when we look at them with a telescope. This picture will help you to understand what is here said.

How does Venus appear when we look at it through a telescope

4. You must remember that neither the planets nor the moon give any light that is their own. The sun shines on

them, and they reflect some of the light to us. But the sun shines only on one side of a planet or moon at one time; and the other side is dark. Sometimes we see but a small part of the side on which the sun shines, and then it does not appear round, nor give much light.

Does Venus shine with her own light? What gives it light? Does the sun shine all around a planet or moon?

5. How delightful it is, to learn our own duty while we are studying these works of the Lord. The sun is the lord of this lower world. It gives light to all those globes that revolve about it; and they send round to each other a part of what the sun gives them. So the Maker and Ruler of all worlds, imparts to us and to all his children the light of our minds, which is Truth; and He requires that each one should impart to others from the light which he receives.

Who gives light to all men? What is that light? What does He require of each one?

6. Mercury and Venus are sometimes called *interior* or *inferior* planets, because their orbits are within the earth's orbit, or nearer to the sun. The orbits of the other planets are without the earth's orbit, or farther from the sun, and they are called *exterior* or *superior* planets.

Why are Mercury and Venus called interior planets? What are those called, that are farther from the sun than the earth is?

CHAPTER V.

THE EARTH, ⊕.

1. The Earth on which we live does not appear like a globe when we look upon it; but it is so large, that we can see only a very small part of it. If the smallest fly or bug were placed on an orange or an apple, it could see but a little distance, and the parts around it would appear rough with hills and valleys, as the earth does to us. But we know that the Earth is a globe or sphere, because many men have sailed round it, which they could not do if it had a different shape There are also other proofs that the Earth is a globe, which we shall attend to hereafter.

What is the shape of the Earth? How is this known?

2. The diameter of the Earth is about 8,000 miles. It turns round on its axis from west to east in about 24 hours, which make one day; and revolves round the sun once in a year, or 365¼.

How many miles is the diameter of the Earth? How many is the circumference? Which way does it revolve on its axis? How long is one revolution on its axis? How long is a revolution round the sun?

3. Be careful to remember, that this Earth is a globe, or ball; that is a planet; that it turns round from west to east on its axis, and that the time in which it turns once round is

called a *day*: that it also goes round the sun, and that the time in which it goes once round the sun is called a *year*.

What things must you carefully remember?

4. If you hold your ball towards the sun or a candle, the light will shine on one half of it at a time. Turn it round from west to east, and each part will come to the light, and then go away from it, every time that the ball turns round. In this way the sun shines on the Earth while the Earth turns round. If a fly were on the ball, the sun or candle would appear to the fly to move from east to west; so while the Earth turns from west to east, the sun appears to move from east to west. This is like what you notice when sailing rapidly in a boat or ship, or riding in a coach: the trees and houses, and fences which you pass, appear to move the other way.

On how great a part of the Earth does the sun shine at once? Why does the sun *appear* to move from east to west?

5. Everything that is on this globe turns round with it; and the air and clouds that are around us, also revolve with the Earth. It is because these things all move round quietly with us, that we do not notice their motion. So, when you sit in the cabin of a large boat or ship, and sail smoothly along, you cannot see that anything in the cabin moves. If you look out upon the land, the things which you there see, appear to move backwards; so, when you look away from the Earth, and see the sun, moon, or stars, they appear to move backwards towards the west, because they do not go with the Earth.

Do you, and the trees, houses, and all things on the Earth, revolve with it once in a day? Why do not these things appear to move? Why do the sun, moon, and stars, appear to move from east to west?

6. We revolve with the Earth once in a day. If we lived at the equator, we should go as far in a day, as it is around the Earth; but we live nearly half way between the equator and the north pole. Now, measure round your ball at the equator; then measure round it about half way from the equator to the pole. You find the distance much less here, than at the equator. Make a little dot at the equator, and another where you last measured round the ball. Now, revolve it slowly; and you can see that the last dot does not go so far in revolving once, as the other does. It revolves in the same time, but goes slower. Those people, therefore, who live at the equator, revolve nearly 24,000 miles in a day: but others revolve slower, and a less distance in a day, in proportion to their distance from the equator.

Do you move as fast with the Earth, as the people at the equator? How far do they move in a day? Why do you not go as far?

7. As the people at the equator are carried about 24,000 miles in a day, they must be carried a twenty-fourth part of

that distance in an hour, and that is 1000 miles. The people of Philadelphia, and other places in latitude 40°, are carried 800 miles in an hour. The people of Boston, and others in latitude about 42½° are carried 770 miles in an hour. The people of St. Petersburgh, and others in latitude 60°, are carried about 500 miles in an hour.

How far are people at the equator carried in a day by the Earth's revolution on its axis? How far in an hour? How far are those carried who live in latitude 40°? Those in latitude 42½°? Those in 60°?

8. You will now understand about the Earth's motion on its axis; and we will proceed to talk for a while of other things.

CHAPTER VI.

THE EARTH, ☽, ⊕.

1. The eleven planets that we have mentioned, are called *primary planets*. Some of them have a small kind of planets that revolve about them, and go with them round the sun. These are called *Moons*, *secondary planets*, or *satellites*. Mercury and Venus have no Moons; our Earth has one; some of the planets have several Moons.

Have Mercury and Venus any Moons? How many has the Earth? Has any planet more?

2. The beautiful Moon, which shines on the earth so sweetly in the night, is 240 thousand miles from us. It revolves round the earth, as a little ball round a large one, in about 29½ days; and it revolves on its axis in the same time.

How far is the Moon from the earth? In what time does the Moon go round the earth? How long is a day at the Moon?

3. The diameter of the Moon is about 2000 miles. To the people of the Moon the earth appears as the Moon does to us, except that it probably appears much larger.

How large is the Moon? How does the earth appear to the lunarians, or inhabitants of the Moon?

4. When we look at the Moon through a telescope, it has a very rugged appearance. Those parts which are brightest are supposed to be high lands and mountains; and the darker parts to be valleys. The cut on the next page will give you some idea of the appearance of the Moon when seen through a telescope.

What are the brightest parts of the Moon supposed to be? What are the darker parts?

5. There is but little air about the Moon, and probably little water upon it. We could not live there; but it is doubtless a very good world for such people as do live there.

Is the Moon supplied with air and water so well that we could live on it?

6. You must remember that the Moon has not any light of its own; it receives light from the sun, and reflects it to us. The earth also receives light from the sun, and reflects it to the Moon and the planets.

Does the Moon shine with its own light? Whence does it receive light? *We shall explain several other important things concerning the Moon in another part of this book.*

CHAPTER VII.

MARS, ♂.

1. We now begin to speak of the planets that are farther from the sun than this earth is. Mars is 144 millions of miles distant, and revolves round the sun in a little less than 2 of our years. It revolves on its axis in about 25 hours.

Is the earth, or Mars, farthest from the sun? How far is Mars from the sun? How long is a year at Mars? If a boy were born at Mars at the same time that you were born, how many years of Mars has he lived? How many years of Mercury? How much longer is a day at Mars, than our day?

2. Mars is about 4,300 miles in diameter. It is not, therefore, more than one third as large as our globe. To the people who live on Mars, this earth probably appears larger than Mars does to us. But Mars is one of the brightest planets, and appears of a fiery red color.

How large is Mars? How does it appear to us?

3. When we look at this planet through a telescope, we can see many curious spots and belts upon it, as in this cut

We know not what is the cause of these appearances. Possibly they may be clouds. Mars has no moon.

What singular appearances are mentioned? Do you know the cause of them? Has Mars any moon?

CHAPTER VIII.

VESTA ⚶, JUNO ⚵, PALLAS ⚴, AND CERES ⚳.

1. We shall speak of all these planets in one chapter, because we know little of them. It is but a short time since they were discovered. Ceres was discovered in 1801, by Piazza of Palermo in the island of Sicily; Pallas, by Dr. Olbers of Bremen, in 1802; Juno, by Mr. Harding near Bremen, in 1804; and Vesta by Dr. Olbers, in 1807. All these planets are very small, and we do not know that they have any moons.

When, and by whom was Ceres discovered?—Pallas?—Juno?—Vesta? Are they large, or small? Have they any moons?

2. Vesta is about 223 millions of miles from the sun. Its year is equal to 3 years and 8 months on this globe. We do not know how long its day is, nor what its diameter is.

How far is Vesta from the sun? How long is its year? Do you know the length of its day?

3. Juno has a very elliptical orbit. Its mean distance from the sun is 253 millions of miles; but it is sometimes much greater, and sometimes much less. Its year is equal to 4 years and 4 months on this earth; and its day is supposed to be 27 of our hours.

What is the mean distance of Juno from the sun? In what time does it revolve round the sun? In what time does it revolve on its axis?

4. PALLAS is sometimes almost twice as far from the sun as at other times. Its mean distance is about 263 millions of miles. Its year is equal to about 4 years and 7 months on this earth. We know not the size of Pallas, nor the length of its day.

How great is the distance of Pallas from the sun? Is it always equally distant? How long is the year of Pallas?

5. CERES is about as far from the sun as Pallas, and its year is of about the same length. The length of its day, and its size, are unknown.

How far is Ceres from the sun? How long is its year?

CHAPTER IX.

JUPITER, ♃.

1. We come now to a planet of great size, which we shall be better able to describe than we were the last four. Jupiter's diameter is 89,170 miles. It is 1400 times the size of this earth; and is the largest planet that we know.

What is the diameter of Jupiter?—the circumference?—its size compared with the earth?

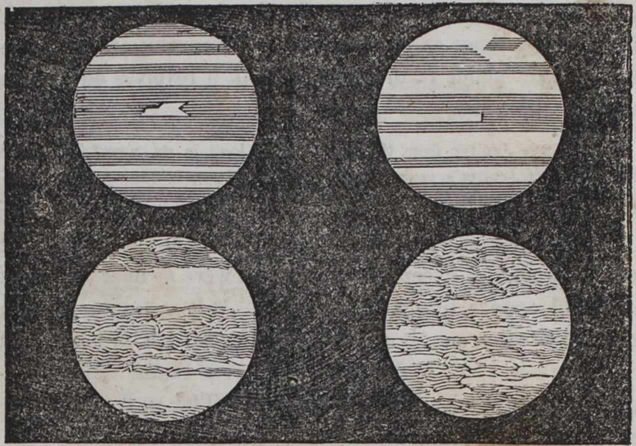
2. Jupiter is 490 millions of miles from the sun; thus, it is about five times as far as we are. Its revolution round the sun requires about 12 of our years; but it revolves on its axis in about 10 hours.

How far is Jupiter from the sun? How long is its year?—its day? How many of Jupiter's years are there in 48 of ours? How many in 96? How many of Jupiter's days are equal to 10 of ours?

3. Jupiter gives us a beautiful light, and it is the brightest of all the planets except Venus. If it were as near as Venus it would appear like a great moon. When Jupiter is seen through a telescope, it appears to be crossed with belts, that change their place and figure at different times. Many singular spots are also seen on its face. The next cut represents some of these appearances.

What is said of the brightness of Jupiter? How would it appear, if it were as near as Venus? How does it appear through a telescope?

4. Now we have something to say, that is very curious. Jupiter has four moons, or satellites, which revolve round it as our moon revolves round the earth. Some of them are smaller than our moon, and some are much larger. They are at very different distances from Jupiter, and revolve round it in different times. One of them goes round in about 2 of our days, and none of them requires more than 17 days. You recollect that our moon requires 29½ days, to go round the earth.



How many moons has Jupiter? What is said of their size?—of the times of their revolutions?

5. The inhabitants of any one place on Jupiter can seldom or never see all the moons at one time, but they frequently see two or three. As the planet revolves in 10 hours, the days and the nights are very short; and neither the sun nor any of the moons can ever be long absent. If we could see all these spots, belts, and moons, as the people of Jupiter do, how strange they would appear.

Are all the Moons of Jupiter often visible at one time? Are they long absent?

6. It is not probable, that the people of Jupiter can see either Mercury, Venus, the Earth, or Mars. All these planets appear nearer the sun to them than Mercury does to us; and the brightness of the sun's light would prevent their being seen. Those planets which are beyond Mars, can be seen from Jupiter, and perhaps others are visible, of which we know nothing.

What planets are probably invisible at Jupiter? Why can they not be seen? What is the *elongation* of a planet? What planets are visible at Jupiter?

CHAPTER X.

SATURN, ♄.

1. Here is another wonderful planet. Saturn is larger than any other except Jupiter. Its diameter is 79,000 miles, and it is 1000 times larger than this earth.

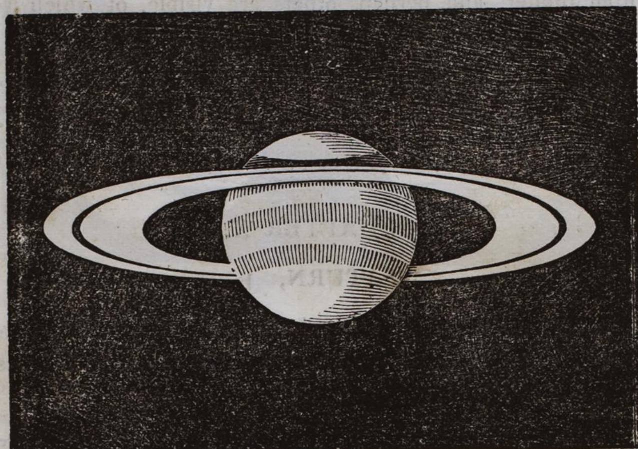
What is the diameter of Saturn? Its circumference? How much larger is it than this earth?

2. Saturn is 900 millions of miles from the sun, and revolves round it in 30 of our years. It revolves on its axis in about 10 hours.

How far is Saturn from the sun? How much farther than the earth? How long is its year?—its day?

3. When seen through a telescope, Saturn appears to be surrounded by two rings. One ring seems to be within the other, and there is a considerable space between them. You can form some idea of them from this cut.

What is said of Saturn's rings ?



4 This singular planet has *seven* moons. They revolve in different times, varying from 1 day to eighty days. These moons and the bright rings, doubtless render the nights at Saturn very light and pleasant.

How many moons has Saturn ? In what times do they revolve ? What make Saturn's nights pleasant ?

CHAPTER XI.

URANUS or HERSCHEL, ♅.

1. The people of the continent of Europe commonly call this planet *Uranus* ; but in England and America it has been more common to call it *Herschel.* It was discovered to be a planet by Dr. Herschel of England, in the year 1781. Many others had previously seen it, but they supposed it to be a fixed star.

When, and by whom, was this planet discovered ? What had others supposed it to be ?

2. Uranus is the most distant from the sun of all the planets that we can see. Its distance is 1800 millions of miles; which is twice as far as Saturn, and nineteen times as far as the earth.

How far is Uranus from the sun ? How much farther than Saturn ?—than the earth ?

3. One revolution of this remote planet round the sun requires 84 of our years. If its inhabitants do not live longer than those of our earth, few of them live to be a year old. The length of their day is unknown.

How long is a year at Uranus ?

4. The diameter of Uranus is 35. 000. It is therefore, the third planet in size, and is 90 times the size of this earth. Six moons revolve round Uranus, but they are so far from us, that we can know little of them.

How large is Uranus? How many planets are larger? How many moons has Hershel?

5. The immense distance of Uranus from the sun would lead us to suppose that it must be very dark and cold. But the people may receive more heat and light from the sun than we are aware of, and they may have better means than we know of for producing light and heat. Their eyes may be fitted to see where we could not; and their bodies may not be so easily affected by the cold. Some animals have eyes that see best where there is little light; and some cannot live except in cold climates. So also, there are some vegetables that will not grow where the climate is very warm; and others cannot bear the cold. He who is the Creator and Preserver of all things, mercifully adapts them all to the stations to which He appoints them, and to the uses which He designs them to perform.

Is it certain that the climate of Uranus is very cold, and that the people have little light? Are animals and vegetables adapted to various degrees of heat and light?

6. We have now described all the planets that we are acquainted with. There may be others so small or so distant that we cannot see them with our telescopes. Five of those which we now know, have been discovered since the year 1780; and if further improvements should be made in the telescope, others may perhaps be seen.

Is it certain that no more planets revolve round our sun? How many have been discovered since 1780? Can you tell which they are?

CHAPTER XII.

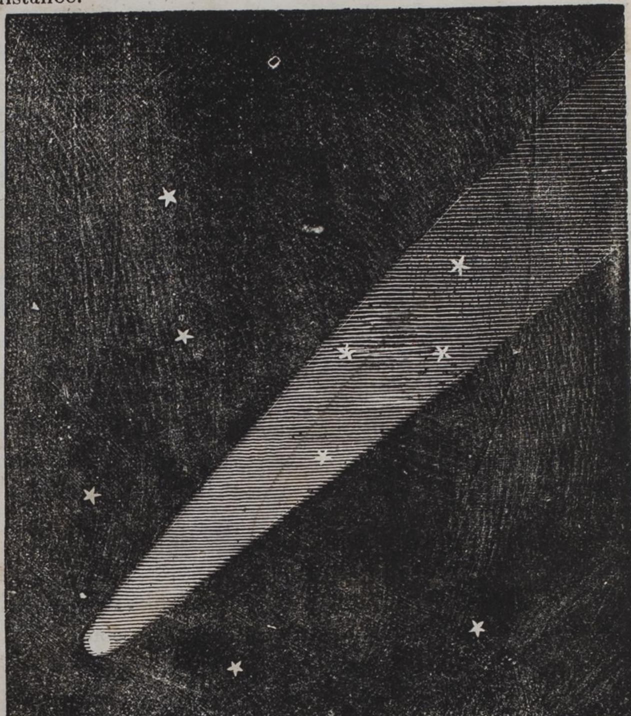
COMETS.

1. There is a class of bodies revolving about the sun, which appear very different from the planets. They sometimes come very near the sun, and are seen by us for a considerable time; and then they go far away, so that they cannot be seen with the best telescopes for many years. They appear somewhat like a planet or star, except that they have a bright train or tail extending from them, and spreading out to a great distance. These singular bodies are called Comets. The cut on the next page represents the Comet that appeared in 1811. Its tail was much longer than it here appears.

Do Comets ever come near the sun? Are they always visible? How do they appear?

2. Although Comets generally appear small like stars, some have been seen which looked as large as the moon. The tails of some Comets are short, and give but little light; but others extend as far as from the horizon to the zenith, or 90 degrees, and give as much light as a small moon. This dif-

ference in their appearance sometimes depends on their distance.



How large have any Comets appeared? How far do any of their tails extend?

3 We do not know enough about Comets, to describe them so well as we can the planets. Only a few, and those not very large, have appeared since astronomers have had good telescopes, and have understood well how to calculate the size, distance, and revolutions of such bodies. About 500 are known to have been seen within the last 1800 years; but the time of revolving round the sun has been determined for only two of them. We cannot tell when the large ones will be seen again.

Why can we not well describe the Comets? How many have been seen within 1800 years? Are the times of their revolutions known?

4. The Comet that is best known is called the Encke Comet, because its revolution was first accurately calculated by Professor Encke of Germany. This is a very small Comet, and revolves round the sun in about 1200 days. It goes nearer the sun than Mercury, and farther from it than Ceres. It never appears large to us.

What Comet is best known? How long is its revolution round the sun? How near the sun does it go? How far from it? Does it ever appear large?

5. It is not four hundred years since Comets were regarded with extreme terror, because they were supposed to be the forerunners of dreadful calamities: but we now regard them

without any fear, and class them among the good things which the Lord has made. They may be inhabited like the planets; but even if they are not, we cannot doubt that they are useful; for what the Lord has made, he made that it might do good.

How were Comets formerly regarded? How are they now regarded? For what did the Lord make all things?

CHAPTER XIII.

METEORS.

1. Meteors are bright bodies, that are often seen darting through the atmosphere. They do not appear to revolve in orbits, like planets and comets, but to fly about in various directions. Some of them are called *falling stars*, or *shooting stars*, and are often seen moving along rapidly, and leaving a long train or tail behind them.

What are Meteors? Do they appear to revolve in regular orbits? What are some of them often called?

2. Meteors commonly appear no larger than a star; but some have been seen that appeared as large as the sun, and brighter than the moon. Most of them move very rapidly, but others slowly.

What is said of the size of Meteors?—of their motion?

3. We are generally incapable of giving any probable estimate of the distance of these bodies. In many cases the same Meteor has appeared in the same manner to persons who were many hundred miles apart. This shows that they are commonly at a much greater distance than they appear to be.

What is said of their distance?

4. In some cases, however, they have been noticed so near, that they were heard to make a loud buzzing noise, as they rushed through the air. Some have also been heard to burs with a tremendous noise; and stones have been seen to fall from them to the ground. In the year 1807, one was seen passing over the town of Weston, in Connecticut. It appeared nearly as large as the sun, and very bright. It burst with a great explosion, and large stones fell to the ground. All the stones that were found, would, perhaps, weigh 300 pounds. They were of a different kind from any that belong to this country; and when they fell, they were hot. Similar explosions have been noticed in other places.

Have Meteors ever been known to be near the persons who saw them? What sometimes happens with them? What is said of the Meteor seen in Connecticut in 1807?

5. It is not, however, supposed, that all Meteors are composed of stones; but we do not know much about them. We are entirely ignorant how such stones happen to be far above the earth, and moving about in every direction. Nei-

ther do we know why they are hot, nor why they are so luminous.

Are all Meteors supposed to be composed of stones ? Is it known how they are produced ?

6. In the year 1779 a most wonderful appearance of Meteors was seen in the eastern sky. Thousands, and probably millions, of Meteors were seen within the space of four hours; and some of them seemed twice as large as the sun. They were noticed at the same time in South America, Labrador, Greenland, and Germany. Their height must have been immense, to be seen, at the same time, at places so far distant from each other; and their size must have been very great, or they could not have appeared so large when at so great a distance.

What is said of the remarkable appearance of Meteors, witnessed in 1779 ?

CHAPTER XIV.

THE FIXED STARS.

1. We have now spoken of the Sun, the Planets, Moons, Comets, and Meteors. We call the SUN the centre of this system; and all the other globes that we have described revolve round the SUN, and depend upon it for light and heat. When we thus speak of the *Solar System*, we mean the Sun, and all the globes that revolve round it.

What is meant by the Solar System ? What bodies have we described, that belong to this System ?

2. But there are other globes in the firmament, that do not belong to this System. Most of those bright twinkling bodies, which you see in a clear evening, are called Fixed Stars. We call them *fixed*, because they have no real motion that we can discover. These Stars are doubtless, suns to other systems; that is, they are like our sun, and have planets revolving round them.

Why do we call these stars *fixed* ? What are they supposed to be ?

3. When you look at the Stars, in a clear evening, their number seems immense, but you really see but few, compared with what you suppose you see. You look at them confusedly, instead of separately and distinctly; and that causes the mistake. You can seldom see more than 1,000 in the finest evenings, unless you look through a telescope

How many Stars can you see at one time without a telescope ? Why do they appear to be so very numerous ?

4. When we look through a telescope we can see many Fixed Stars that are otherwise invisible; but all of them are at so great a distance, that a telescope does not have any effect to bring them near, and make them appear larger, as it does the planets. If they were not more than 200 thousand times farther from the sun than this earth is, we could estimate their distance; but no one of the Fixed Stars is within that immense distance

Can we see more Stars with a telescope, than we really see without one? Does a telescope, magnify them, as it does the planets? How far from the sun might they be, and, yet, their distance be estimated?

5. We often see a broad belt extending from northeast to southwest, which appears somewhat like a white cloud, and seems to be filled with an infinite number of small Stars. This belt is called the *Milky Way* or *Galaxy*. When we look at it through a telescope, we find that it does actually consist of very great numbers of Stars, which are divided into clusters.

What is the white belt called, extending from north east to southwest? Of what is it composed?

6. The Stars were divided into clusters or *constellations*, by persons who lived several thousands of years ago; and names were given to the constellations, and also to the principal Stars in each cluster. One of these clusters is called Orion: the yard L, is nearly in the middle of it. Another is called Pleiades, or the Seven Stars. Both of those are mentioned in the book of Job, which is supposed to be the oldest in the world. The ancients reckoned 50 constellations. Modern astronomers have added many others.

Who divided the Stars into clusters, and named them? In what ancient book are two of them mentioned? How many clusters did the ancients reckon?

7. If you have a celestial globe, you may see about 100

constellations named, and also the names of the largest Stars. The Stars are reckoned in six classes, according to their size. The largest class are said to be of the *first magnitude*; those considerably smaller are of the *second magnitude*. Thus they are numbered to the *sixth* class, which are the smallest that can be seen without a telescope.

How many constellations are now reckoned? Into how many *magnitudes* are the Stars divided?

8. There are many other things respecting the Fixed Stars, which you will find it very interesting and useful to learn when you are a little older. But you are old enough now, to consider how great, and manifold, and full of wisdom and goodness, are the works of the Lord. Behold the Fixed Stars, which are so many Suns, with Planets revolving round them; and these Planets, with their Moons, are peopled with innumerable beings, who daily receive the rich blessings of the Divine Providence. When the Lord had made these things, He saw that they were VERY GOOD. They are called GOOD, because He made them *to do good*. You are made for the same purpose, and you should be diligent and faithful to perform it.

For what purpose did the Lord make all things?

CHAPTER XV.

THE FOUR SEASONS.

1. We have given a general account of the Sun, Planets, Moons, Comets, Meteors, and Fixed Stars; and we shall now explain more fully several important things respecting the planet on which we live, and the moon that revolves round it.

Of what have we given a general account? Of what are we now to give a more full explanation?

2. There are four Seasons, viz. Spring, Summer, Autumn, and Winter. Spring is partly cold and partly warm; Summer is quite warm; Autumn is generally mild; and Winter is very cold. These different Seasons are caused by the different manner in which the sun shines on us, at these different periods of the year.

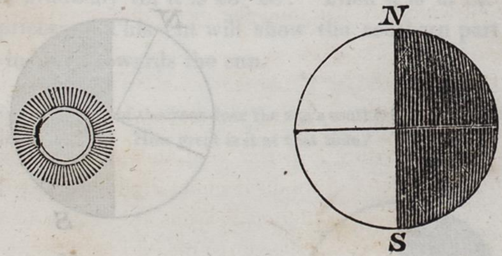
How many seasons are there? What is said of each? What causes the different Seasons?

3. You will recollect that the earth revolves round the sun once in a year, or in 365¼ days. During a part of the time that the earth is thus going round, the equator is turned directly towards the sun, as you see by the cut opposite.

When the sun shines thus on the earth, those persons who live at the equator have it directly overhead every day at noon. We live considerably north of the equator, and therefore the

sun is never vertical, or directly overhead; and it is so with those who live far south of the equator. The days when the sun is exactly vertical at the equator, are the 20th of March, and the 22d of September.

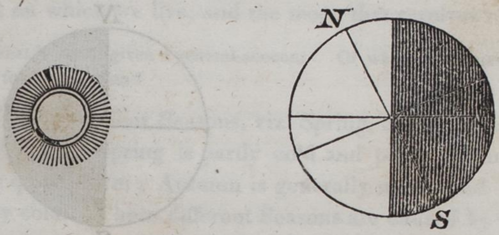
At what times of the year is the sun directly overhead at the equator?



4. From the 20th of March to the 21st of June, the north part of the earth is turned gradually more and more towards the sun; so that the sun is vertical one degree north of the equator, and then two degrees, and so on, till it is 23° 28′ north of the equator. That happens on the 21st of June.

This degree of latitude on the earth is called the Tropic of Cancer. It passes over the island of Cuba, across Mexico, the southern cape of California, the island of Formosa, China, and many other countries, as you may see by a map. This cut will show you how the earth is so turned, that the sun shines more directly on the northern parts of it.

During what period is the northern part of the earth inclining more and more towards the sun? How far north of the equator is the sun ever vertical? When is it so far north? What is that line round the earth called, on which the sun is vertical on the 21st of June?



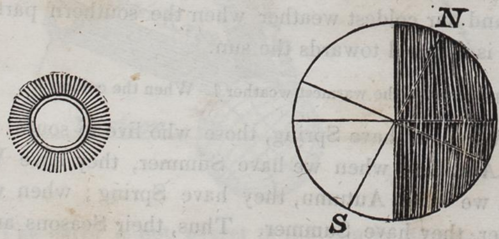
5. From the 21st of June, the earth is gradually turned so that the *declination* of the sun diminishes every day till September 22d. By the *declination* of the sun we mean its apparent distance from the equator at noon. When it is vertical at the equator, it has no declination; when it is any number of degrees north or south, we say its declination is so many degrees.

When does the earth get turned back, so that the sun is vertical again at the equator? What appears by the 4th paragraph to be the greatest north-

ern declination of the sun? In other words—How far north of the equator is it ever vertical? Remember what the *declination* of the sun means.

6. From the 22d of September until the 22d of December, the southern part of the earth is gradually inclined towards the sun. Then the sun has southern declination, or is vertical to places south of the equator. Its declination increases gradually till it is 23° 28′. Then it is at the Tropic of Capricorn. This cut will show the southern part of the globe inclined towards the sun.

During what part of the year does the sun's southern declination increase? When is it greatest? How great is it at that time?



7. From December 22d to March 20th, the earth gradually comes back to the position that makes the sun shine vertically at the equator. Then it has completed a year, and has had the sun vertical *once*, as far north as the Tropic of Cancer,

twice at every place between the Tropic of Cancer and the Tropic of Capricorn, and *once* at the Tropic of Capricorn.

When does the earth turn back, so that the sun is vertical at the equator? How many times in a year is the sun vertical at the Tropics?—at all places between the Tropics?

CHAPTER XVI.

THE FOUR SEASONS CONTINUED.

1. You can now see that we have our warmest weather when the northern part of the globe is inclined towards the sun, and our coldest weather when the southern part of the globe is inclined towards the sun.

When have we the warmest weather? When the coldest?

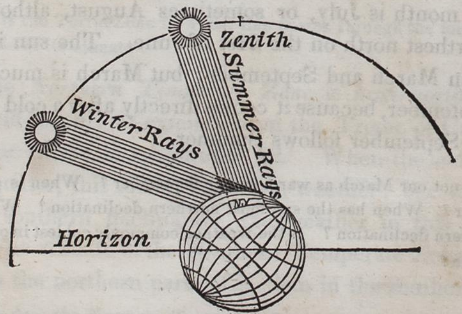
2 When we have Spring, those who live in south latitude have Autumn; when we have Summer, they have Winter; when we have Autumn, they have Spring; when we have Winter, they have Summer. Thus, their Seasons are opposite to ours.

What Season have the people of New Holland, the southern part of Africa, and the southern half of South America, when we have Spring?—When we have Summer?—When we have Autumn?—When we have Winter?

3. By the following cut you will plainly see why the sun

gives us more heat in Summer than in Winter. Look carefully at it, and observe how much more oblique or slanting the Winter rays are, than the Summer rays; and that more of the latter fall on any given space, than of the former. Thus you will understand why we have less heat in proportion as the sun's rays fall obliquely. If you do not fully comprehend this, ask some one to assist you.

Why have we less heat in Winter than in Summer?



4. The earth is not nearer to the sun in Summer than in Winter; on the contrary, it is a little nearer in Winter. If that has any effect, it tends to make the Summer in south latitude a little warmer than the Summer in north latitude, for the earth is nearest the sun, when it is Summer in south latitude.

When is the earth nearest the sun ?

5. After the earth on this part of the globe has become quite cold by a Winter, it requires considerable time to get warm; and after it has become quite warm, it requires considerable time to grow cold. For this reason, the weather does not become warm in Spring till the sun has been this side of the equator some weeks; and when it has become warm, it continues to grow warmer, even after the sun begins to return from the Tropic of Cancer towards the equator. Thus our warmest month is July, or sometimes August, although the sun is farthest north on the 21st of June. The sun is at the equator in March and September; but March is much colder than September, because it comes directly after a cold Winter, whereas September follows Summer.

Why is not our March as warm as our September ? When is our warmest weather ? When has the sun most northern declination ? When has it most southern declination ? Is the weather commonly coldest in our climate at that time ?

CHAPTER XVII.

THE FIVE ZONES.

1. From what we said in the last two chapters, you will find it very easy to understand the meaning of the Zones.

All that part of the earth that ever has the sun vertical, is called the *Torrid Zone*. You will see that it extends an equal distance each side of the equator. This part of the globe is always warm. There is no winter; and snow and ice are never seen, except on the tops of very high mountains. The sun is vertical over every part of this Zone twice in a year.

Where is the Torrid Zone ? What line passes through the middle of it What is said of its climate ?

2. The *Northern Temperate Zone* is next northward of the Torrid Zone. It extends from the Tropic of Cancer to the Arctic Circle, in latitude 66° 32.′ When the sun is north of the equator, this Zone has warm weather; but when the sun has southern declination, the weather in this Zone is cold. The climate of the Northern Temperate Zone is much colder in the northern parts of it, than in the southern.

How far does the Northern Temperate Zone extend ? What is its climate ?

3. The Southern Temperate Zone extends from the Torrid Zone to the Antarctic Circle in latitude 66° 32′ south. The climate of this Zone is like that of the Nothern Temperate Zone; but it has opposite seasons, as we showed in the last chapter.

Where is the Southern Temperate Zone? What is said of its climate?—of its seasons?

4. The Frigid Zones extend from the Polar circles to the Poles. When the sun's declination is one degree north, it shines continually without setting, for a space of one degree from the North Pole. As the sun's northern declination increases from March 20th to June 21st, the space where it revolves without setting becomes broader. Its breadth from the Pole is just equal to the sun's declination; so that on the 21st of June the whole of the Northern Frigid Zone has constant day. If you look at the figure on p. 48, you will see that the sun shines round the North Pole for a considerable distance, when that part of the earth is turned towards the sun

Where are the Frigid Zones? When the sun's declination is 5° north, how much of this Zone has constant day? How much when the sun is at the Tropic of Cancer?

5. As the sun's declination diminishes, this space also diminishes which has constant day; and on the 22d of September the sun ceases to have any northern declination. Observe that when it is constant day in the Northern Frigid Zone, it is constant night in the Southern Frigid Zone; and just so much of one of these Zones has constant night, as there is of the other that has constant day. So, as the sun has southern declination from September 22d to March 20th,

the Southern Frigid Zone has then its summer and its long days.

When there is constant day for 10° about the North Pole, what is there for 10° about the South Pole? When the sun's declination is 20° south, where is there constant day?—where is there constant night?

6. Although the days are very long in summer in the Frigid Zones, and during a part of the time the sun is constantly visible, yet its rays fall so obliquely that they do not make the weather warm for many days at a time. The snow and ice remain in many places during the whole year. Scarcely any thing grows near the Poles for the support of man or of beast. The winters are intensely cold, and are rendered extremely dismal by the darkness.

What is the climate of the Frigid Zones? Why is it not very warm in summer?

CHAPTER XVIII.

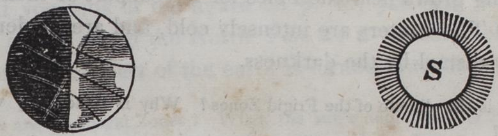
DAY AND NIGHT.

1. From what has already been said, you probably understand the cause of day and night; but it may be useful to attend more to the subject, and repeat some things that we have said.

2. The earth revolves on its axis from west to east in 24 hours, or one day. As it makes a complete revolution or circuit in 24 hours, it moves a twentyfourth part of it in 1 hour; and a twentyfourth part of 360°, is 15°. Thus the earth turns 15° in an hour.

In what time does the earth revolve on its axis? How many degrees does it turn in an hour?

3. While the earth is turning round, the sun shines on but one half of it. That half has day, and the other half has night. Hold your ball in this manner towards the sun or a



lamp, and then turn it slowly from west to east, and you will explain to yourself the cause of day and night.

On how great a part of the earth does the sun shine at any moment?

4. Now, stick a little piece of paper on your ball nearly half way between the equator and the North Pole, and call it the *United States*. Turn the ball so that the *United States* will be on the top of it, or directly under the zenith. When it is *noon*, the sun shines on the country where we live, just as it will on the piece of paper upon your ball.

Where is the zenith? How are you to hold the ball with the *United States* on it, so as to show how the sun shines on us at *noon*?

Observe that you must do this at noon, or else turn the ball so as to make the sun shine on it as it would at noon.

5. Now turn the ball from west to east about one quarter of a revolution. A little fly or bug, standing on that paper, would now see the sun towards the west, just setting. Turn it further, and the sun could not be seen. When the paper comes to the nadir, or the point opposite the zenith, it is situated as we are at *midnight*. Turn the ball further till the fly could see the sun, and you will observe that it would see it *rise* in the *east*.

If a fly stood on the paper while you revolve the ball, where would it see the sun set? Where would it see the sun rise?

If the scholar find this explanation too difficult, he must be careful to obtain assistance from some one who will make it perfectly plain.

6. In the chapter on the Seasons you saw that the sun shines more on the northern hemisphere when its declination is north, and more on the southern hemisphere when its declination is south, and equally on both hemispheres when it has no declination. The sun has no declination when it shines vertically at the equator, that is, on the 20th of March and the 22d of September.

What is meant by the *declination* of the sun? When does the sun shine most on the northern hemisphere?—on the southern hemisphere? When does it shine equally on both?

7. The 20th of March is called the *vernal equinox*, and the 22d of September is called the *autumnal equinox*. They are called *equinoxes*, because the nights and days are then equal in every part of the globe; that is, the nights are 12 hours long, and the days are 12 hours long, at the equator, and in north latitude, and in south latitude.

What are the *equinoxes*? How long are the days at those times?—the nights? Are they the same in all places?

CHAPTER XIX.

DAY AND NIGHT CONTINUED.

1. During all the time that the sun's declination is north—namely, from March 20th to September 22d—the days are longer than the nights in the northern hemisphere. They grow longer every day till June 21st, and then diminish, as the sun's declination does, till September 22d.

What part of the year is the sun's declination north? What effect has that upon the days in the northern hemisphere? During what time are they gradually becoming more than twelve hours long?

2. At the equator the days and nights are of about equal length at all seasons of the year; but a little north of the equator the days are a little longer than the nights when the sun's declination is north; and the farther north we go, the greater is the length of the days during that period.

Where are the days and nights always about equally long? Does the length of the days increase as you go farther towards the pole?

3. The following table will show the length of the longest day in several degrees of latitude.

Latitude.	*Longest Day.*		*Latitude.*		*Longest Day.*	
Deg.	Hours.	Min.	Deg.	Min.	Days.	Hours.
0	12	00	66	32	1	0
12	12	42	68		42	1
20	13	12	70		64	14
30	13	56	72		82	7
32	14	6	74		96	17
34	14	16	75		104	1
36	14	28	78		122	17
38	14	38	80		134	5
40	14	52	82		145	7
42	15	4	84		156	5
44	15	18	85		161	5
50	16	10	87		171	22
55	17	8	89		181	22
60	18	30	90		187	$6\frac{1}{2}$

What is the length of the longest day in latitude 20°?—in latitude 40°?—in latitude 72°? What is the length of the longest day at the city of Mexico?—at Philadelphia?—at Boston?—at St. Petersburg?—at Spitzbergen?—at Cape Horn?—at Potosi?

4. The two hemispheres are directly opposite in respect to the length of days and nights, as they are in respect to seasons. When those who live in north latitude have longer

days than nights, those who live in south latitude have shorter days than nights. Our longest day and their shortest day is June 21st. Our shortest day and their longest day is December 22d. Their nights are always as long as our days, and our nights as long as their days. Observe, however, that in all calculations of this kind you must have respect to the latitude of places, as we have in the following questions.

When the day is 13 hours long in latitude 40° north, where is the night 13 hours long? When the night is 16 hours long in latitude 60° north, where is the day 16 hours long? When there are shorter days than nights in south latitude, are they the same in north latitude? What is the longest day in north latitude?—in south latitude? What is the length of December 22d in latitude 60° south? *See the Table.*

5. When you know the length of a day, substract it from 24, and it will leave the length of the night. Subtract the length of the night from 24, and it will leave the length of the day.

When our days are 16 hours long, how long are our nights? When our nights are 13 hours 20 minutes, how long are our days? How long is the shortest night, where the longest day is 22 hours?

6. When you know the time of sun-rise at any place, double it, and you will have the length of the night. Double the time of sun-set, is equal to the length of the day.

When the sun rises at 5 o'clock, how long is the night? How long then is the day? When the sun sets at half past 7, how long is the day? How long then is the night?

7. At all places nearer the poles than the polar circles are, the sun revolves without setting during a part of the year, and without rising during an equal part. The longest day, therefore, in all these places, is more than 24 hours; and the longest night is of the same length. At the poles, the sun shines constantly for six months, and is absent for six months. *See the Table.*

Where are the longest days more than 24 hours? How long is the longest night where the longest day is two months? How many days are there in a year at the north pole? How many nights? How many nights in a year at the south pole? How many days are there in a year, where the sun shines continually for sixty of our days, and does not rise for sixty days? *The time when it is constantly seen, and the time when it is constantly absent, properly make one day. Sixty and sixty make* 120. *Subtract this from* 365 *and add the* 1 *day to the remainder, and it will give the answer.*

8. There is about a week when the sun is very near the Tropic of Cancer, and another week when it is very near the Tropic of Capricorn. During those times it changes its declination very little; and, therefore, it rises and sets at nearly the same time for several days. Thus, we have several days that are almost as long as the longest, and several almost as short as the shortest. These times, about the 21st of June and 22d of December, are called the *solstices.* The former is the *summer solstice*; the latter the *winter solstice.*

When is the summer solstice?—the winter solstice?

9. For some time before the sun rises, and after it sets, it shines upon the air and clouds so as to give considerable light. This time in the morning and evening is called *twilight*.

What time is called twilight?

10. Near the equator there is but a very short time of twilight. Almost as soon as the sun sets, dark night commences. But as we go toward the poles, the time of twilight increases; and in some parts of the frigid zones where the sun is absent for several months, there are many days of twilight.

Where is there little twilight? Where is there a great deal?

CHAPTER XX.

DIFFERENT PHASES OF THE MOON.

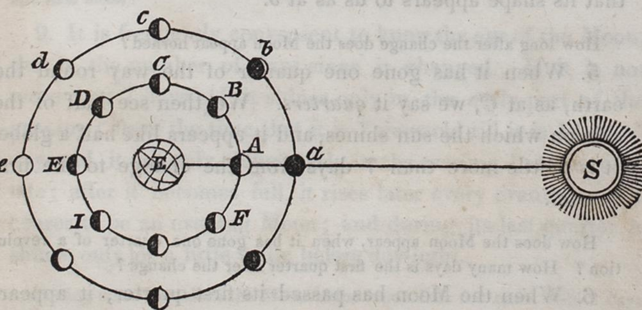
1. By the different *phases* of the Moon, we mean its different *appearances*. You know that it sometimes appears *horned*, in this manner, ☾. Sometimes it is like half a globe; and sometimes it is like a whole globe, thus, ☉. Its face does not look black like these marks; but these marks show its different shapes.

What is meant by the *phases* of the Moon?

2. In order to understand the cause of these appearances, you must recollect again, that the Moon revolves round the

earth once in 29½ days: that the Moon is a dark body like this earth, and only gives light when the sun shines upon it; that the sun shines upon only one half of the Moon at one time, and therefore one half of it is dark: and that the sun shines only a part of the time on that side of the Moon which is towards the earth.

In what time does the Moon revolve round the earth? Is the Moon a luminous body, like the sun? Whence does it receive light? How great a part of the Moon is enlightened by the sun at one time? Does the sun always shine on that part of the Moon which is towards us?



3. Now examine this figure carefully. *S.* is the Sun; *E* is the Earth; *A*, *B*, *C*, *D*, *E*, represent the Moon in different parts of its orbit. When the Moon is between, or nearly between, the earth and the sun, its dark side is directly towards the earth. This will appear plainly from the Cut: for

when the Moon is at *A.* only the dark side of it is towards *E*; and it would appear to one who stood at *E.* as it does at *a* This is the state of the Moon, when we say it *changes*, and becomes *new moon.*

What state of the Moon is represented by its appearance at *A* ?

4. One or two days after the Moon changes, it is so far east of the sun, that we can see a small part of the side upon which the sun shines. For three or four days it continues to be *horned.* See how the sun shines on it at *B*; and observe that its shape appears to us as at *b.*

How long after the change does the Moon appear horned ?

5. When it has gone one quarter of the way round the earth, as at *C*, we say it *quarters.* We then see half of the side on which the sun shines, and it appears like half a globe. It is a little more than 7 days from the change to the first quarter.

How does the Moon appear, when it has gone one quarter of a revolution ? How many days is the first quarter after the change ?

6. When the Moon has passed its first quarter, it appears more than half round, because we see more than half of the side on which the sun shines. It is then called *gibbous*, and appears as you see at *d.*

When the Moon is more than half round, what do we call its shape ?

7. When it is opposite the sun, as at *E*, we see all that side of it that is enlightened; as at *e.* It is then *full moon.*

When is it *full moon* ?

8. By looking at the remainder of the figures, you will see that the Moon *wanes* or decreases from *full moon* till *new moon*, as it *waxes* or increases, from *new moon* till *full moon*; and that it has the same phases or appearances during the two quarters before *new moon*, as during the two quarters after *new moon.*

During which part of the Moon's revolution is it said to *wax?* During which is it said to *wane* ? What phases has the Moon between *full moon* and *new moon ?*

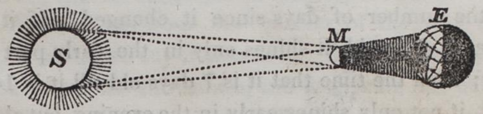
9. It is frequently convenient to know the *age* of the Moon, that is, the number of days since it changed. If it is not more than 7 days old, it shines only in the early part of the evening; from the time that it is 7 days old till it is 14 or 15 days old, it not only shines early in the evening, but also quite late; after it becomes full, it rises later every evening, till it ceases to be an evening Moon; and during its last quarter it shines only for a little while before day-light.

During what time does the Moon shine when it is not more than 7 days old?—from 7 days to 14 or 15 days old?—after it is full?—during its last quarter?

CHAPTER XXI.

ECLIPSES OF THE SUN.

1. We have mentioned that the moon revolves round the earth once in 29½ days. It sometimes comes directly between the Sun and the earth, so as to prevent the Sun from shining on some part of the earth. This is the cause of an *Eclipse of the Sun.* This cut will show you how the moon's shadow falls on the earth, and prevents our seeing the Sun.



What causes an eclipse of the sun?

2. When the moon hides the whole face of the Sun, there is a *total eclipse*: when it hides only a part of the Sun, it is a *partial eclipse.* Sometimes it hides all except a small rim or ring, and that makes an *annular eclipse.* Total eclipses and annular eclipses are very uncommon.

Define the three kinds of eclipses.—Which are uncommon?

3. The shadow of the moon can cover only a small part of the earth. For this reason we see but few of the eclipses of

the Sun, and but few are seen by the people of any particular part of the globe.

Is there ever an eclipse of the Sun at all places on the earth at the same time? Do we see all the eclipses that happen?

4. The following Table will tell you what great eclipses of the Sun will be seen in America during the remainder of this century.

1834, Nov. 30.	It will be *total* in South Carolina.
1836, May 15.	It will be *annular* in the West Indies.
1838, Sept. 18.	It will be *annular* in the western part of Connecticut, in New York, New Jersey, Pennsylvania, Maryland, Delaware, Virginia, and North Carolina.
1854, May 26.	It will be *annular* at Boston, and a part of New Hampshire and Maine.
1865: Oct. 19.	It will be *annular* in North Carolina and South Carolina.
1869, Aug. 7.	It will be *total* in North Carolina and Virginia.
1875, Sept. 29.	It will be like the eclipse of 1854.
1900, May 28.	It will be *total* in Virginia.

When will the next total eclipse of the Sun occur in any part of the United States? When will the next annular eclipse occur in Boston?—in New York?

5. The last total eclipse of the Sun in any part of the United States, was in 1825; but that was total only in a small part of Florida. The last that was seen by us, was in June, 1806. There will not be another that will be total in any part of New England during this century.

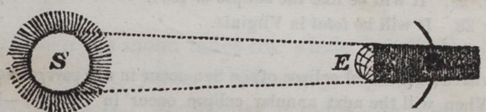
When was the last total eclipse of the Sun in any part of the United States? When was the last that was seen by the people of several of the States? Will there soon be another in New England?

CHAPTER XXII.

ECLIPSES OF THE MOON.

1. The Moon sometimes passes through the shadow of the earth, and that causes an *Eclipse of the Moon.* Hold up your ball to the sun, and it will cast a shadow for a considerable distance. The earth casts a great shadow for a very great distance. When the Moon is in this shadow, the sun does not shine on it

What ca ses an eclipse of the Moon?



2. Sometimes only a part of the Moon passes through the earth's shadow, and then there is only a *partial eclipse*; but when the whole Moon passes through the shadow, there is a *total eclipse.* There cannot be an *annular eclipse* of the Moon.

How is a *partial eclipse* of the Moon caused?—a *total eclipse?*

3. Eclipses of the Moon are also called *lunar eclipses.* Although no eclipse of the Sun is visible on a large part of the earth, yet every eclipse of the Moon is visible to all who can see the Moon. We therefore see more lunar eclipses than solar eclipses.

What other name is given to eclipses of the Moon? Are they visible on more of the earth than solar eclipses? Do we see more solar eclipses, or lunar eclipses?

4. An eclipse of the moon can only happen at the time of *full Moon.* An eclipse of the sun can only happen at the time of *new Moon.* But, there is not an eclipse of the sun at every new Moon, nor an eclipse of the Moon at every full Moon.

When do lunar eclipses happen? Is there an eclipse of the Moon at every full Moon? When do solar eclipses happen? Is there an eclipse of the sun at every new Moon?

5. The causes of eclipses of the Sun and Moon have been known only a few centuries. Especially when a total eclipse of the Sun occurred, the ancients were filled with wonder and fear. But we are now as well able to account for eclipses, as for any more common event; and we can calculate the exact times when they occurred in past ages, and will occur during thousands of years to come.

Have the causes of eclipses been long known? Can they now be accurately calculated?

CHAPTER XXIII.

LEAP YEAR.

1. We have already stated that the earth revolves round the sun in $365\frac{1}{4}$ days; and, as we call one revolution a year, we are obliged to reckon 365 days to each year for three successive years, and 366 days to every fourth year. The years that have 366 days, are called *leap years.*

What are *leap years?*

2. The day that is added, in order to make leap years have 366 days, is always added to February. For three successive years February has but 28 days; and every fourth year it has 29 days.

To what month is the day added to make leap year have 366 days? How many days has February in leap year?

3. To ascertain when it is leap year, divide the year by 4, and if there is no remainder, that year is leap year. If there is a remainder, that remainder will show how many years have passed since leap year. Thus: take the year 1831, and divide it by four, and the remainder will be 3. It is, therefore, 3 years since leap year, and consequently the next year will be leap year. Divide 1832 by 4, and see whether we have judged right. You will find that there is no remainder.

How do you ascertain when it is leap year? If there is a remainder after dividing by 4, what does it show? How long after leap year, was 1827? Was 1816 leap year? How many days were there in February in 1820? How many in 1813?

4. This mode of measuring years, or the periods of the earth's revolutions, is very nearly correct, but is not perfectly so. Adding one day in every four years, is a little too much and therefore the day is omitted once in a century. Thus, the year 1800 was not reckoned leap year, although it was the fourth after leap year, and could be divided by 4 without any remainder. So the year 1900 will not be reckoned as leap year. By thus omitting once in a century to add the one day to every fourth year, we measure the time with such exactness, that several thousand years will not make an error of one day in our manner of measuring the earth's revolutions.

How often is it necessary to omit adding one day when the year can be divided by 4 without any remainder?

CHAPTER XXIV.

ATTRACTION.

1. There are several kinds of attraction; and you will understand them when we mention some examples. A load-stone attracts iron, and this is called *magnetic attraction* or the *attraction of magnetism.* Take a load-stone, or a piece

of iron that has been rubbed with load-stone, and hold it near any very small piece of iron or steel; and you will see that it *attracts* or *draws* it.

What will a load-stone attract? What kind of attraction is this?

2. The little particles that compose a piece of wood, stone, apple, lead, iron, and most other things, attract each other. It is because the particles attract each other, that these things keep their proper shape, instead of crumbling into dust. This attraction, which makes the particles of bodies cohere, or stick together, is called the *attraction of cohesion.*

What prevents your ball from crumbling into little particles of dust?

3. If you keep one corner of a handkerchief dipped in water, the whole handkerchief will soon become wet. So, if you dip one end of a piece of sugar in your tea, the sugar will attract the tea, and make it rise so as to wet the whole. This is called *capillary attraction.*

If I dip one part of a sponge in water, the whole will soon be wet; what kind of attraction causes this?

4. The attraction which causes bodies, that are above the earth, to fall towards it, is called the *attraction of gravitation.* When your feet are tripped, you fall towards the earth, and not towards the clouds. Throw a stone into the air, and it will not go far; the earth will attract it, and pull it down.

Why do bodies fall towards the earth? What kind of attraction is it that prevents your jumping to the moon?

5. The *attraction of gravitation* also makes all kinds of bodies have weight. Their weight is not always in proportion to their size; for a pound of sponge is much larger than a pound of lead. The lead is more *solid* or *dense*, and therefore has more matter in the same bulk. All bodies are attracted by the earth in proportion to their quantities of matter, and their weight is in the same proportion.

What makes bodies have weight? Why is a bushel of stones heavier than a bushel of corn? Which is most dense, corn, feathers, or iron? In what proportion are bodies attracted by the earth? In what proportion are they heavy?

6. Observe that the *density* of bodies is not the same as their *hardness.* Lead is more *dense* than stone or iron, but it is not so *hard.* We know that lead is the most *dense*, because it is the *heaviest*; and we know in the same way that it has the most matter in it. Platina is the most *dense* substance, and therefore the *heaviest*, that we are acquainted with. Gold is next in *density* and *weight.* But there are many substances much *harder* than platina or gold. The *attraction of cohesion* makes bodies hard, but the *attraction of gravitation* makes them heavy.

Is the *density* the same as the *hardness* of bodies? What is the most *dense* and *heaviest* substance that we know? What is next in *density* and *weight*? What makes bodies *hard*? What makes them *heavy*?

7. As all bodies are attracted to the earth in proportion to their quantities of matter, they are in no danger of falling or going away from the earth. It makes no difference whether they are on one side of the earth, or on another; for the earth attracts nearly equally on all parts of its surface. This is the reason why people may live on all parts of the earth, notwithstanding it is round, and is turning round very rapidly every moment. Besides this rapid motion on its axis, the earth goes 68 thousand miles every hour in its orbit round the sun. Still, we are in no danger, of falling off, and being left behind to fly in the air.

What keeps all bodies from falling off from the earth? Are they attracted on all sides of the earth? How fast does the earth move round the sun?

CHAPTER XXV.

ATTRACTION CONTINUED.

1. We have said that the earth attracts all bodies in proportion to their quantities of matter; and it is also true, that other bodies attract each other. My desk attracts my inkstand, knife, scissors, books, spectacles, and all other things that are near it; and all these things attract each other. A large mountain attracts with considerable power, and causes

the clouds to gather round it, and leave water to form the springs.

Do nearly all bodies attract each other? Why do the clouds gather about the mountains?

2. All bodies have the power of attraction in proportion to their quantities of matter; and the earth has so much more matter than any of the bodies that are on its surface, that its attraction is incomparably greater. For this reason we seldom notice the attraction of small bodies for each other; all are so much attracted by the earth, that they seem not to be drawn by each other.

In what proportion have all bodies the power of attraction? Why do we not feel the attraction of a tree, a mountain, or a house? When you drop an apple or a stone, why is it not drawn away to some tree, mountain, or rock, that is near?

3. The earth is supposed to attract all bodies more, the nearer they are to its centre. A stone, or bird, or any thing else that is far above the earth, is less attracted than it would be nearer the earth. The moon is a great way off, but still it is somewhat attracted by the earth, and also attracts the earth. If the earth and moon were nearer each other, the attraction between them would be greater. So all other bodies, when near each other, attract more than when distant. A mountain will not draw a cloud to it, that is many miles distant.

Does the earth attract bodies when they are near it, more than when they are distant? Do the moon and the earth attract each other? Would they attract less, or more, if they were nearer?

4. The sun has a great deal more matter in it, than any planet, or any thing else that we know. It has, therefore, immense power of attracting the planets and all things in this solar system. It does not attract the things on this earth so much as the earth does, because it is so far distant; but it attracts the earth and all the planets enough to keep them revolving in their proper orbits.

What object has more matter in it, than any other that you know? What does the sun attract? When you throw up a stone, does the earth, or the sun, attract it most? What keeps the earth and the other planets revolving in their proper orbits?

5. If you fasten a stone, or any other body that will weigh two or three pounds, to one end of a string, and swing it round you rapidly with the other end, you will find that it pulls you quite hard. The faster you make it revolve, the more it will draw you. You thus perceive that it has a tendency to fly away in a straight line, instead of revolving in a circle. If you let go the string when the body is revolving rapidly, it will thus fly away for some distance.

When you twirl a stone round you with a string, or a sling, does it incline to come towards you, or to fly away? Has it a tendency to move in a straight line, or in a circle?

6. When you are twirling the body round you, it draws you with considerable force; and that force is called the *centrifugal force.* You have to exert considerable force to prevent its flying away from its proper circle or orbit; and that force is called the *centripetal force.*

What is that force called, which keeps a body that is revolving, from going to the centre of its orbit, or draws it away from the centre? What force is that, which is required to prevent a body that is revolving, from flying away in a straight line?

7. Now, consider that the sun and earth attract each other, and therefore have a tendency to come together. This is the *centripetal force.* By revolving rapidly round the sun, the earth has a tendency to fly away out of its orbit. This is the *centrifugal force.* These two forces are exactly equal to each other; and therefore the earth is not drawn to the sun, nor does it fly away from it in a straight line; but it revolves round the sun continually, in a regular orbit, as you make a stone revolve round you, when you twirl it with a string.

What force is the attraction between the sun and the earth called? What opposite force is just equal to this? What is the effect of these two forces?

8. In the same manner all the planets are attracted by the sun, and are prevented by their centrifugal force from being drawn to it; and in this way they are all kept in their proper orbits. So, likewise, the earth and moon attract each other; and the centrifugal force which the moon acquires by revolving round the earth, prevents their coming together, and

keeps them at their proper distance. The moons of the other planets are regulated in the same manner.

Are all the planets kept within their proper orbits in the same manner as the earth is kept in its orbit? What prevents the moon from flying away? What prevents its coming to the earth? Why do not Jupiter's moons go away to the sun, or some other planet? Why do they not fall upon Jupiter, and kill the cattle and the inhabitants?

CHAPTER XXVI.

TIDES.

1. We have shown that the earth attracts the moon, and keeps it in its orbit. The moon also attracts the earth, and has a great effect on the water and the air. The moon's attraction raises up the air and the waters of the ocean on that side of the globe that is turned towards the moon, and makes them much higher than they are in other places. This is the cause of *Tides*.

What effect has the moon's attraction on the waters of the ocean?

2. The sun's attraction has also some effect on the water; and when the sun and moon are both on the same side, or on opposite sides of the earth, they produce the greatest tides, which are called *spring tides*. When the sun is on our side, and the moon is half way round to the opposite side, the attraction of one counteracts that of the other, and they produce the least tides, which are called *neap tides*.

How are *spring tides* caused? How are *neap tides* caused?

3. There are two tides in a day; for there is one tide on the side of the earth next to the moon, and one on the opposite side. The water is about 6 hours in rising or *flowing*, and 6 hours in falling or *ebbing*.

How many tides are there in a day? During how many hours is it *flood tide*? During how many is it *ebb tide*?

4. The tides occur later from day to day, as the moon rises later; but it is not far from half a day from high water to high water again, or from low water to low water again.

Do the tides constantly occur at the same hour of the day?

5. The tides are not equally high in all places. Some parts of the ocean rise 50 or 60 feet; and other parts do not rise more than two feet.

Are the tides equal in all places? How high are they ever known?

CHAPTER XXVII.

TIME.

1. When the sun comes to the meridian of any place we call it noon at that place; but it does not come to the meri-

dian of every place at the same time, and therefore it is not noon at every place at the same time. Those places that have the same longitude as the place where you are, have 12 o'clock and other hours when you have. Those that are one degree east of you, have 12 o'clock and other hours 4 minutes earlier than you have; and those that are one degree west of you, have all times 4 minutes later than you have. Allow 4 minutes for each degree, or one hour for 15 degrees, and you can easily count the difference of time between any two places. You must reckon the nearest way from one place to another, so as not to make the difference more than 12 hours.

When it is noon in Boston how much after noon is it at a place 10° east of Boston? When it is 4 o'clock at Albany, how much does it want of 4 at Buffalo?—at Cincinnati? When it is midnight at New Orleans, what time is it at London? How much earlier does the sun rise at Philadelphia than at St. Louis?—than at Lima?—than at Mexico? How much later does the sun rise at Natchez, than at Norfolk?—than at Paris in France?—than at Rome in Italy? *Find the difference of longitude between the above places, by a gazetteer, or globe.*

FINIS

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