The Solar System

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AUTHOR

A Ready Reference Handbook

TITLE

of the SOLAR SYSTEM

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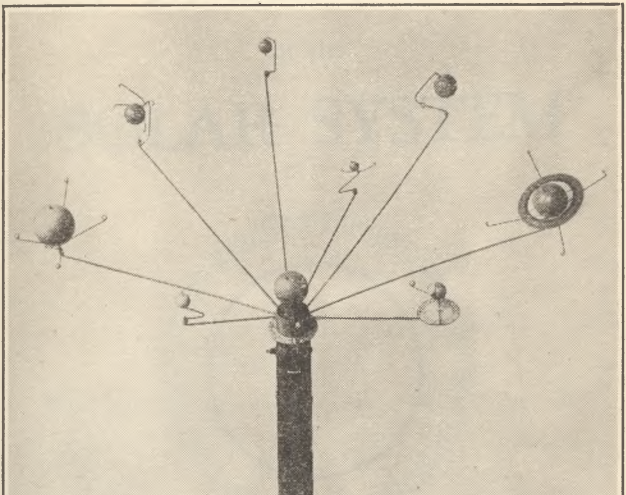
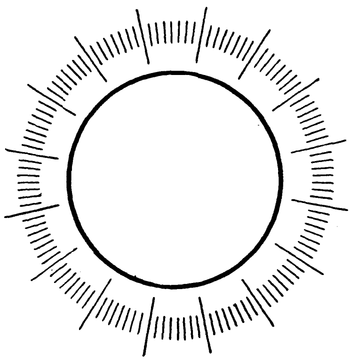
THE MODEL PLANETARIUM



See Appendix

— A —
Ready Reference Handbook
of the
SOLAR SYSTEM



A CONCISE SUMMARY OF OVER

1,000
Interesting Items and Deductions

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2 Christie St., London, Ont.

Dedication

This handbook is dedicated to the amateur astronomers who have done so much to make their inspiring hobby popular.

PREFACE

This little volume is the result of several years of careful search in many libraries in Canada and the United States for the most informing and reliable data about the various members of the Solar System. Our object is to furnish the reader with a simple summary of fact and theory so that he may obtain an adequate understanding of this very interesting part of astronomical study.

Most of the material in these pages was published in the Journal of the Royal Astronomical Society of Canada in recent years. Some necessary brief chapters have been added and for the sake of uniformity in treatment as well as for easy reference and comparison the same number and order of items has been given for each member of the System, although some do not apply in the case of the sun and the earth.

It will be noted that the first thirty items have to do with the body itself while the last thirty deal with the orbit and orbital relations.

The planets within the earth's orbit are often spoken of as "inferior" and those outside of it "superior", while those within the orbit of the planetoids have been called "minor" or "inner" and those outside "major" or "outer." In this handbook we shall use only the terms "inner" and "outer" as separated by the planetoid orbits.

In expressing large numbers we shall use the well-known French System of numeration, viz.:—units, thousands, millions, billions, trillions, quadrillions, quintillions, sextillions, septillions, octillions, nonillions, decillions, etc. The best way to read a large number is to count the commas in it except one and translate into the latin; e.g. 5,250,000,000 is read 5 billion, 250 million while 7,385,462,100,000,000 is read 7 quadrillion, 385 trillion, 462 billion, 100 million.

Many thanks are due to Professor C. A. Chant, of the University of Toronto, for reading the manuscript and making some much-needed corrections, and to Professor H. R. Kingston, of the University of Western Ontario, for numerous excellent and valuable suggestions.

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CONFIGURATIONS

Of An Inner and an Outer Planet.

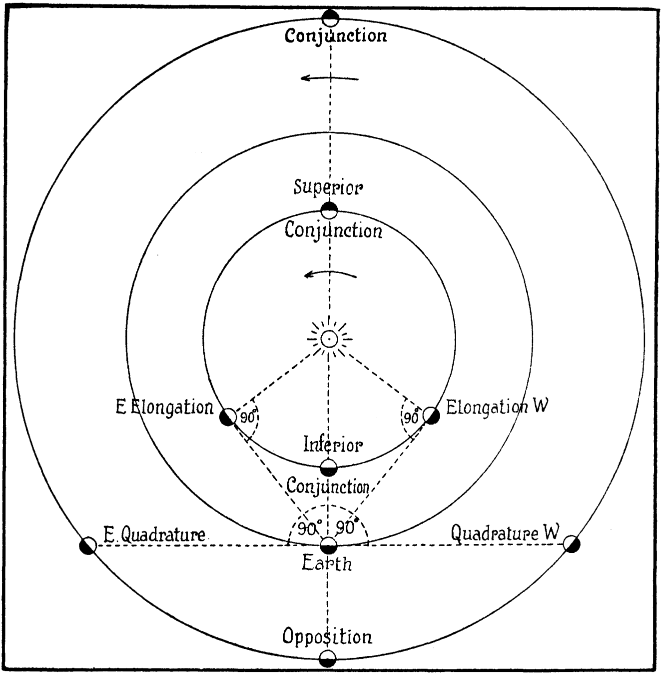

FIG. I.

Since the planets revolve round the sun, their configurations, as seen from the earth, occur at different points in their orbits, and the planets therefore appear in different constellations through the months and years.

COMPARATIVE DIAMETERS
Of the Sun and the Planets

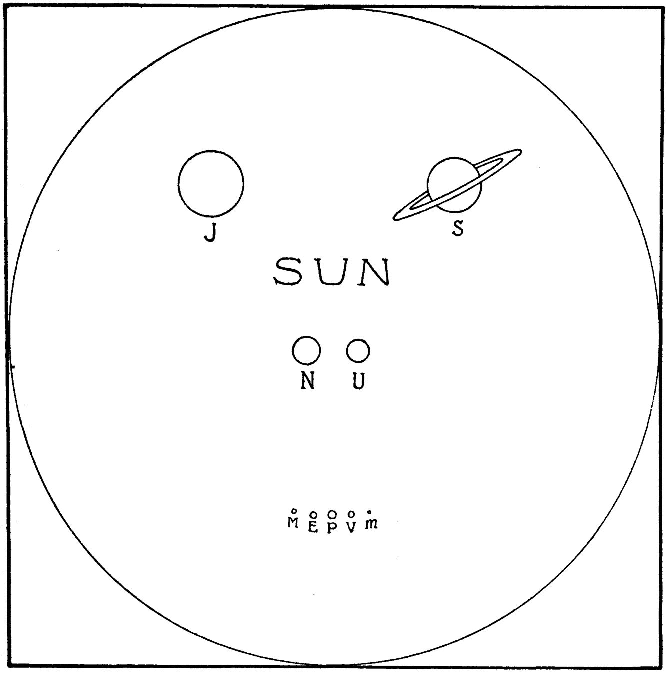

FIG. II.

The mass of the sun is so enormous, about 2,000,000,000,000,000,000,000,000,000 (2 octillion) tons, that out of it some 750 sets of planets or about 333,000 earths could be formed.

THE THEORETICAL ELLIPTICAL ORBITS

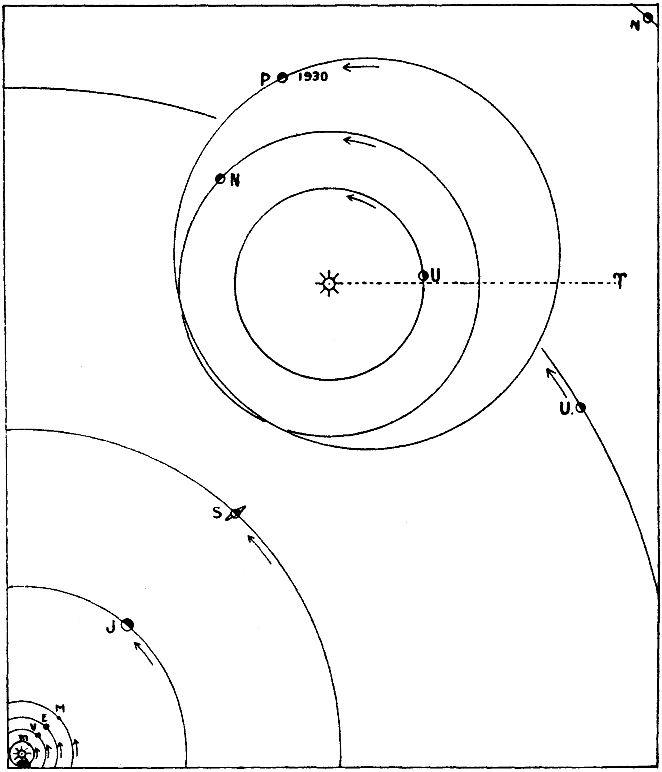

FIG. III.

The orbit of Pluto lies far beyond the limits of this page but is indicated in the circle above. Its position when discovered is marked. In about 60 years it will be near its perihelion within Neptune's orbit but high above it and then we shall have a little better opportunity to observe it.

THE ACTUAL HELICAL PATHS

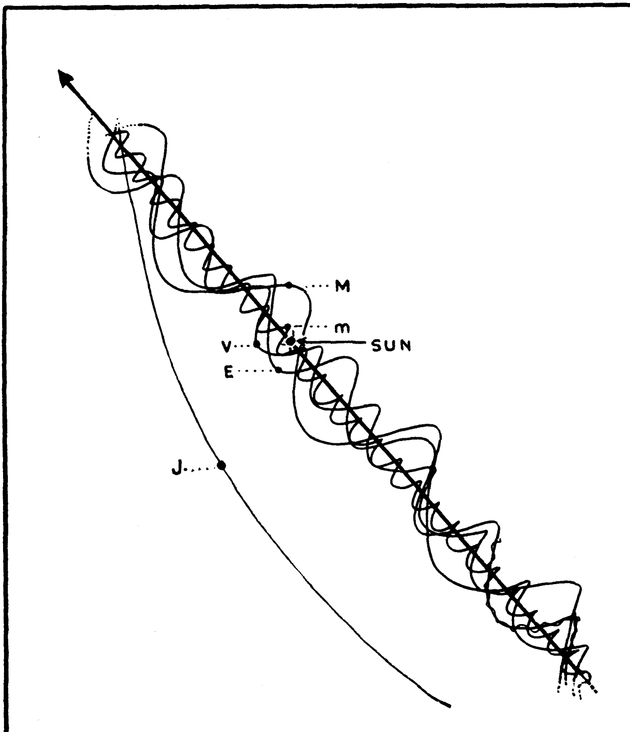

FIG. IV.

This is the picture of a wire model built to scale to illustrate the flight of the Solar System toward Vega. The limits of our space prevent us from showing more than five paths but they are all worked out in detail in the text. See item 36.

THE POINTS OF PERIHELION AND APHELION

And the Lines of Apsides.

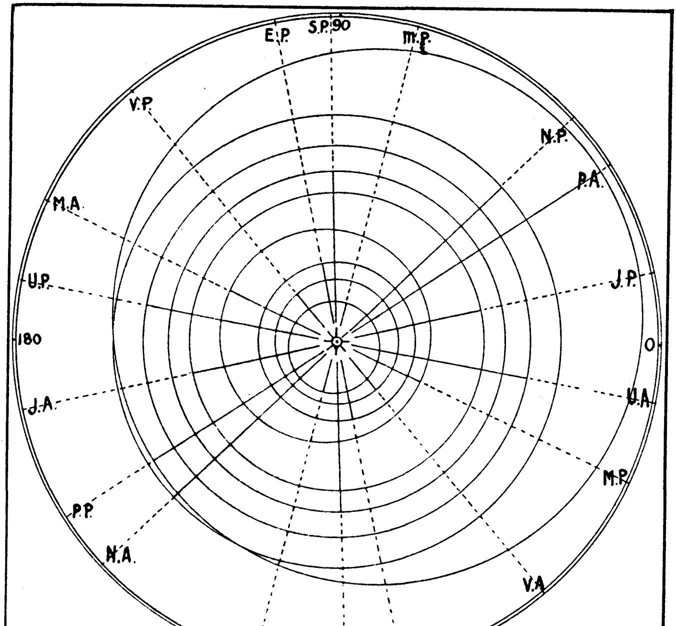

FIG. V.

This page is taken as in the plane of the ecliptic and these orbits are not drawn to scale but merely to indicate the positions of perihelion and aphelion and the apsidal lines, which divide the orbits into equal parts and mark the major axes.

THE NODAL POINTS AND LINES

For Angles of Inclinations, See Fig. vii.

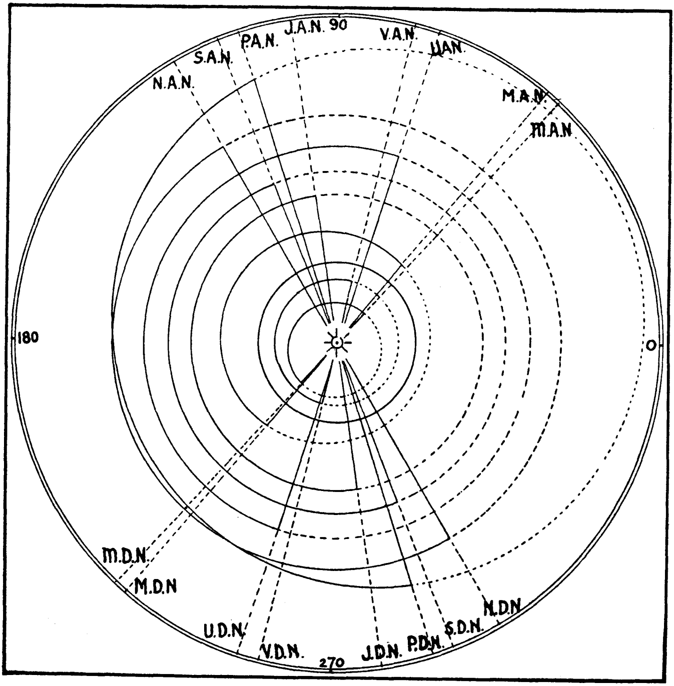

FIG. VI.

This page also is taken as in the plane of the ecliptic and these orbits, like the others, are merely for the purpose of indicating the positions of the nodes and nodal lines, which do not divide the orbits into equal parts on account of their eccentricity. The dotted part of each orbit lies below and the undotted part above the ecliptic.

INCLINATIONS OF PLANETS AND ORBITS

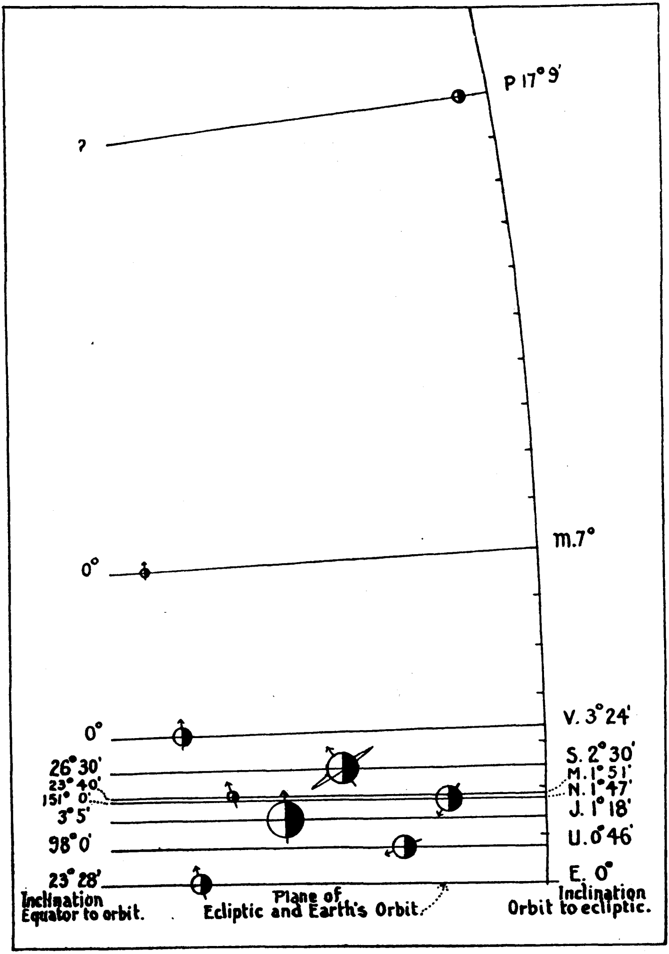

FIG. VII.

THE RELATION OF THE CELESTIAL EQUATOR TO THE ECLIPTIC

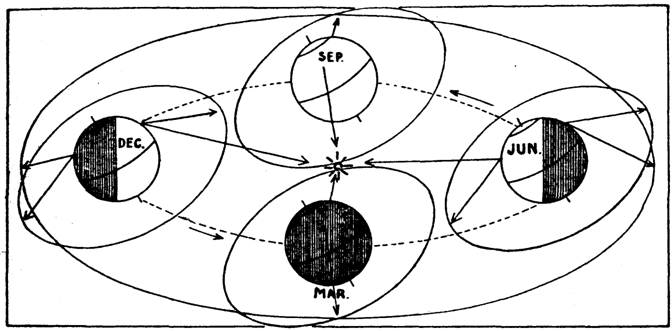

FIG. VIII.

For the sake of clearness we have shown the earth at the four special positions in the orbit and have indicated the celestial equator in each position by a small ellipse. Our position on the earth at this latitude is near the point where the arrows leave the earth.

About March 21 the earth arrives at the place where the equinoxes are in line with the sun and the celestial equator intersects the ecliptic and night and day are equal because the sun is thereby directly over our equator. Now, from the night side of the earth, we see the autumnal equinox in the sky at one intersection which comes to the meridian at midnight on that date, while from the day side we see the sun at the other intersection which is the vernal equinox.

About June 20 the earth arrives at the point where the solstices are in line with the sun and from the night side we see the ecliptic, marked by the moon and the planets, 23° 28′ below the celestial equator, while from the day side we see the sun on the ecliptic the same distance above the equator at the summer solstice which is its highest northerly point for the year.

About September 22 the earth arrives at the other place where the equinoxes are in line with the sun and the celestial equator intersects the ecliptic and night and day are again equal because the sun is once more over the equator. Now, from the night side, we see the vernal equinox in the sky at one intersection which comes to the meridan at midnight on that date and is called sidereal noon, while from the day side we see the sun at the other intersection, which is the autumnal equinox.

About December 21 the earth arrives at the other point where the solstices are again in line with the sun and from the night side we see the ecliptic, marked by the moon and the planets, 23°28′ above the celestial equator, while from the day side we see the sun on the ecliptic the same distance below the equator at the winter solstice which is its lowest southerly point for the year.

Then the earth moves on to March only to begin again. Between these special positions the relation of the equator and the ecliptic is gradually changing as the earth continues on its endless journey round and with the sun.

It is thus easy to see the reasons for the apparent rise and fall of the ecliptic during the year. There is also the apparent diurnal rise and fall due to the rotation of the earth and our horizon plane. See Chap. II.

INTRODUCTION

It is necessary only to remind the reader that the Solar System is composed of the sun, the planets, the planetoids, the satellites, the comets and the meteors. That the sun is an ordinary star of average dimensions and probably of middle age. That since the discovery of the new planet Pluto the diameter of our system has become about 8,000,000,000 miles. That the orbits of the bodies revolving round the sun are not closed ellipses round a sun at rest, as usually described, but open helical paths round a sun in motion on its flight through space at about 397,600,000 miles per year. See Figure IV. and Items 36. That the Solar System is probably situated in one arm of our Stellar System or Galaxy perhaps 60,000 light years (350 quadrillion miles) from its centre and in almost the same plane. That the Galaxy, apparently bounded by the Milky Way, is possibly 250,000 light years (1 and ½ quintillion miles) across and about 1/10 of that distance in axial diameter and that it is but one of thousands of similar spiral nebulae which are found in outer space apparently receding from us.

A careful comparison of the data of many astronomical authors disclosed a large number of differences regarding some of the items so that we have struck safe averages in the hope that the student, from extra reading, will keep them up to date. The writer suggests that some enterprising young astronomers undertake a complete new series of observations, measurements and calculations for the Solar System.

A model system built to scale is useless as a demonstrating device on account of the great distances of the planets as compared with their diameters, so the writer has devised a simple form of planetarium for class-room and for individual study. See Frontispiece and Appendix.

The information here given is modern and reliable although some items in course of time may need to be revised as better instruments are developed and more accurate measurements are made possible.

CHAPTER I.

THE ORIGIN AND FUTURE OF THE SOLAR SYSTEM.

Many attempts have been made to solve this age-old problem of origin. Philosophers have offered their able assistance but it remained for the great LaPlace, in 1796, to formulate the Nebular Hypothesis according to which the sun originated in an enormous concentration of nebulous matter whose rapid rotation caused the separation of irregular portions which, like the central sun, gradually became spherical and formed the planets. In recent years, however, this theory has been found mathematically inadequate.

Another suggested solution called the Planetesimal Hypothesis was worked out in 1900 by Chamberlin and Moulton, of Chicago, according to which the development of the Solar System began in a nebulous condition with a central rotating star round which great clouds of gas and myriads of planetesimals revolved. While in this attenuated condition the larger planetesimals in their revolution swept up vast quantities of the nebulous matter and became the planets. The satellites were formed in a similar manner.

A third solution is the Tidal Theory proposed by Sir James Jeans in 1916, in which a more massive passing star is supposed to have caused enormous tides on the sun which gradually broke away and became the planets. In this early stage some of the planets had very eccentric orbits and thus during perihelion passage came quite close to the sun which, like the passing star mentioned above, caused tides on the planets which also broke away and became the satellites.

The future of the Solar System and of the universe is also a matter of much conjecture. On the one hand, some physicists think of it as a mechanism running down or wearing out by the gradual conversion of matter into radiation and that it is only a question of time when the sun will be unable to supply sufficient radiant energy to maintain the normal temperature of the earth, so that it along with the other planets will gradually become frigid and lifeless. Even the sun itself will cease to shine and the Solar System become invisible in the black darkness of space. The universe as a whole must follow the same unhappy course. This is the so-called "heat death" theory which, while receiving some support from certain mathematical considerations, nevertheless smacks of worn-out deistic philosophy.

On the other hand, there are those who strongly favor the theory of constant rehabilitation by atomic recreation from interstellar space as being far more likely than gradual permanent decadence. We cannot think of the universe as we know it today without a supreme intelligence entirely outside the time-space condition, and since we are compelled to posit such we are unable to conceive of a merely decadent creation. Indeed we may safely declare that there can be no such condition as unretrieved decadence in the sense of heat-death, but only change and development according to universal physical law. To use the word evolution except in a purely technical sense is to befog the issue with ambiguity, because of the possibility of a variety of interpretations of the term.

The amateur will recognize these attempts at the solution of these great problems to be only suggested theories and in no sense possessing the authority of the last word. That the Bible and science are at variance here is not true, because the former declares accomplished facts while the latter deals only with the detailed processes involved.

CHAPTER II.

THE BASIS OF PLANETARY MEASUREMENTS.

It is hardly necessary to say that the sky is not a huge dome but simply space scattered with stars. For purposes of study, however, it is conceived of as a great hollow sphere with the observer at its centre. The sky does not revolve, its apparent motion from east to west is due to the rotation of the earth in the opposite direction. Keep this ever in mind.

The Zodiac is that band of constellations 16 degrees wide round the sky through the midst of which the imaginary ecliptic circle passes and marks the apparent annual path of the sun among the stars. The chief members of the Solar System revolve within this band.

In astronomy, as in geography, certain imaginary points and circles are used. The circles are called co-ordinates and act as guides for observation as well as reference lines for measuring stellar positions. The group of co-ordinates most commonly used for stellar work is the Equator System with the celestial equator as its fundamental circle, the celestial poles as its poles, the Vernal Equinox as its first point, and its purpose the determination of Right Ascension and Declination. Another is the Ecliptic System used to determine celestial latitude and longitude of the stars and planets. It is not used much.

To make clear the relation between the Celestial Equator and the Ecliptic we must always remember that the former is merely a projection of the earth's equator far out among the stars, while the Ecliptic is merely a projection of the earth's orbit far out among the stars. The planes of these two great circles are fixed, the former with reference to the earth and the latter with reference to the sky, at an angle of 23 degrees 28 minutes from each other. Thus as the earth passes round the sun and keeps the equatorial plane at this fixed angle, the Ecliptic which is also fixed seems to gradually rise above and fall below the celestial equator and makes its changing position somewhat difficult to follow. This, however, can be mastered if one will persist in becoming acquainted with the constellations of the zodiac and the position of the Vernal Equinox. The former must be done by observation with star map and flash-light, and the latter by drawing an imaginary eye-line from Polaris to the leading star of Cassiopeia and onward just within the right side of the square of Pegasus to the point where the equator and ecliptic intersect. See Fig. VIII.

Stellar Magnitudes are determined according to certain arbitrary scales devised by astronomers.

Angular Diameter is measured by telescopic observation with a graduated circle, a vernier and a microscope. This is followed by triangulation.

The linear diameter of a body is found by dividing the number of seconds of arc in its angular diameter at mean distance from the earth by the number of seconds in a radian and multiplying the result by the mean distance of the body from the earth. The linear diameter of the moon will be 1874″/206,265″x238,850 or about 2,163 miles.

The circumference is found by doubling the mean radius and multiplying it by 3.1416.

The surface area is found by squaring the mean radius and multiplying it by 4 times 3.1416.

The volume is found by cubing the mean radius and multiplying it by 4/3 of 3.1416.

The density is found by dividing the mass by the volume. The density of water is the unit.

The surface gravity is proportional to the product of its density and its radius. Velocity of escape is deduced from this.

The mass is measured by the attraction of one body for another. The earth's mass is the unit.

The period of rotation is determined by the careful observation of surface markings. The velocity of rotation is deduced from this and the number of days in a planet's year is found by dividing the minutes required for the planet's revolution by the minutes required for its rotation.

The oblateness of a body is expressed in a ratio obtained by dividing the difference between the polar and equatorial diameters by the equatorial.

The amount of solar radiation per unit area a planet receives varies inversely as the square of its distance from the sun.

The albedo is expressed as a ratio obtained by dividing the amount of light a planet reflects by the amount it receives from the sun.

The temperature is measured by means of a tiny electric thermocouple which can even register the temperature of any selected area.

The nature of the atmosphere is determined by the telescope, the spectroscope and thermocouple.

The parallax is obtained by very careful telescopic observation with a graduated circle, a vernier and a microscope. Then triangulation.

The distance from the earth is found by dividing the number of seconds of arc in a radian by the number of seconds of mean horizontal parallax of the body and multiplying the result by the length of the earth's equatorial radius in miles. The distance of the moon will be 206,265″/3423″x3,963 or about 238,850 miles.

The dimensions of an orbit are found by plotting the planet's course from a number of its observed positions among the stars.

The eccentricity is a ratio obtained by dividing the number of miles the sun is out of centre by the number of miles in the semi-major axis of the orbit. It is really the sun that is out of centre or eccentric while the orbit is elliptic and helical.

The inclinations are found by observation and comparison with the plane of the ecliptic which is the plane of reference.

The helical path of a planet during each revolution is determined by geometry. A base-line equal to the circumference of the plane orbit is laid down; to this at one end erect at right angles a line equal to the distance traversed by the sun in the planet's year; now complete the triangle and the hypotenuse becomes the helical path. Square and add the first two then take the square root and you have the distance.

The other items are explained in the text.

CHAPTER III.

SOL, THE SUN.

1. NAME—Most ancient peoples worshipped the sun and thus a variety of names have been given to it. Among the Egyptians it had three names: Horus at dawn, Amen-Ra at noon, and Osiris at its setting. Among the Babylonians its name was Bel, later Marduk and still later Shamash, with two others, Ninib in the morning and the spring, and Nergal at noon and in the summer. The Greeks called it Helios the all-seeing and hearing one. The Romans named it Sol the lone one and Phoebus Apollo the brilliant one. The Incas of Peru said they were the children of the sun.

2. MYTH—Phoebus Apollo was god of the sun as his sister Diana was goddess of the moon. He was the son of Jupiter and Latona and was supposed to foster archery, music and prophecy.

3. SYMBOL—☉ A circle with its centre probably representing one of Apollo's sun-chariot wheels or the sun in the centre of an orbit.

4. SOUND—In the Music of the Spheres the sun was supposed to be the great organ that unified the sounds of the then known planets.

5. COLOUR—Its colour is usually yellowish but varies from pale yellow to blood red according to its position in the sky as seen through our ever-changing atmosphere.

6. MARKINGS—The entire surface is enveloped in gaseous vapors which are constantly moving about in turbulent fashion. With a telescope one can see the rice-grain texture, the white torch-like faculae, the waving flames called flocculi and the much studied spots and the prominences of luminous gas.

7. STELLAR MAGNITUDE—Since the sun is so near to us compared to the other stars its magnitude is very high, about −26.5 or about 25 magnitudes brighter than Sirius, although Sirius is in reality about 28 times as bright as the sun.

8. GREATEST BRILLIANCY—Solar effulgence is greatest during the period of least sun-spots.

9. ANGULAR DIAMETER—Mean 32′4″ of arc. This is almost the same as that of the moon so that they seem to be about the same size, but we must remember that the moon is only about 1/390 as distant as the sun.

10. LINEAR DIMENSIONS—The actual diameter is about 866,000 miles or 400 times that of the moon and 109 times the earth. Its equatorial circumference is close to 2,720,000 miles.

11. AREA OF SURFACE—About 2,356,000,000,000 square miles or some 12,000 times that of the earth. The sun's surface is gaseous.

12. VOLUME—Probably 340,000,000,000,000,000 cubic miles or about 1,300,000 times the size of the earth.

13. MASS—About 333,000 times the earth or 2,000,000,000,000,000,000,000,000,000 tons from which some 750 sets of planets could be formed.

14. DENSITY—This is 1.39 of water or .25 of the earth or equal to soft coal. It is about 1,000 times as dense as our air and this low density is probably related to the enormous heat.

15. SURFACE GRAVITY—27.6 times that of the earth so that a person weighing 150 pounds here would weigh over 2 tons on the sun. His frame would crumple under the load.

16. FALLING BODIES—The velocity of such objects during the first second would become about 440 feet per second. Over 27 times what we experience.

17. VELOCITY OF ESCAPE—384 miles per second or over 55 times what we experience and due to the sun's enormous mass and the consequent force of gravity.

18. PERIOD OF ROTATION—This varies with the latitude. At the equator it is 24.6 days, at latitude 30° it is 26.5 days, at latitude 45° it is 27.5 days, and at latitude 80° it is 33.3 days. This is determined by the motion of the spots and by the

rotational approach and recession of the sun's limbs as seen in the spectroscope.

19. VELOCITY OF ROTATION—The sun rotates on its axis from west to east like the planets. At the equator its speed is about 4,450 miles per hour while at latitudes farther north and south the velocity decreases.

20. DAYS IN ITS YEAR—We are not yet certain of the circumference of the sun's orbit so we cannot determine the number of days in its year.

21. MAGNETISM—This is said to be a special characteristic of all rotating bodies. It is not the same as gravitation which is universal, but is localized in each individual body. The amount of the sun's magnetism is enormous and we know that it often affects atmospheric conditions on the earth, especially at and during the maxima of sun spots which are highly polarized. The magnetic poles of the sun, like those of the earth, are situated near but not at the axial poles.

22. OBLATENESS—There seems to be neither polar flattening nor equatorial bulge, the rotation being only about 4 times as fast as that of the earth.

23. DIRECTION OF AXIS—The celestial point toward which the north pole of the sun is directed is at Right Ascension 18 hours 44 minutes and Declination +64°, that is between Vega and Polaris while its south pole points in the direction of the southern constellation Columba. The apex of the sun's way, but not the end of its journey, is quite close to this at R. A. 18 hrs. and Decl. +28°. This makes the sun's path nearly parallel to its axis so that it is flying head-first toward Vega.

24. INCLINATION, EQUATOR TO ORBIT—7°15″. The sun's apparent orbit is the ecliptic, so this angle causes the north pole of the sun to lean away from the earth in March and toward it in September, in other words the sun's equator arches upward in the spring and downward in the fall, while in the summer and winter seasons it assumes a slightly oblique position. This inclination determines the aim of the sun spots which are never far from its equator when they are present. In the spring most of the spots shoot above the earth, in the fall most of them

shoot beneath the earth, but in both summer and winter the earth is a very good target.

25. LIBRATION IN LATITUDE—These are very small and need not be considered here.

26. LIBRATION IN LONGITUDE—These also are very small and unimportant.

27. SOLAR RADIATION—Radiant energy is propagated in the form of waves of different lengths for different colours. Those of 1/40,000 of an inch in length or 7800 Angstrom units with a frequency of about 400,000,000,000,000,000 vibrations per second produce red, those of 1/50,000 or 5800 A. with about 590,000,000,000,000,000 vib. per sec. produce yellow, and those of 1/70,000 or 3900 A. with about 800,000,000,000,000,000 vib. per sec. produce violet. Longer waves of slower vibrations beyond the red are called infra-red and produce heat and Hertzian or radio impulses, while those shorter, faster ones beyond the violet are called ultra-violet and produce the Rontgen or X rays as well as the gamma and cosmic rays. In the case of ordinary yellow light enough waves are produced in one second to reach 186,300 miles which is the estimated speed of light.

The total energy emitted by the sun per second is given by some as 460,000,000,000,000,000,000,000 horse-power of which the earth receives 1/2,200,000,000 or about 230,000,000,000,000 horse-power, but others say it is 508,000,000,000,000,000,000,000 horse-power which gives the earth 231,000,000,000,000 horse-power, which is about 4,690,000 horse-power per square mile per second. The rest of the Solar System intercepts only about 10 times as much. The vast remainder spreads out in all directions through space, perhaps by some law, to reform and help maintain the almost constant energy of the universe.

The total light is said to actually weigh about 4,000,000 tons per second and to be something like 3,000,000,000,000,000,000,000,000,000 candlepower or equal to 600,000 full moons. The solar constant of radiation is 1.94 calories per minute on each square centimeter of surface exposed to the sun. There is a small variation of about 5% but not enough to affect the earth. A periodicity of about 25 months and 20 days has been announced.

28. ALBEDO—This being a ratio of reflecting capacity only, we do not speak of it in connection with the sun.

29. TEMPERATURE—The average surface temperature is about 5,800°C. or 10,500°F. The total heat emitted in 2 hours and 40 minutes could melt a sphere of ice as large as the earth. The interior is estimated at about 18,000,000° C. or nearly 40,000,000°F. The pressure at the centre is said to be something like 40,000,000,000,000 atmospheres or about 600,000,000,000,000 pounds per square inch. Some interesting theories have been suggested to account for this vast energy:—

a. Combustion—the burning up of the material of the sun—now no longer considered tenable.

b. Contraction—the result of gravitational force now discarded by most physicists.

c. Meteoric showers—a constant rain of cosmic material—now considered wholly inadequate.

d. Cooling down—the heat-death theory—now believed to be only part of the process.

e. Disintegration of radium—an atomic change—but this is too fast since radium loses half in about 1600 years. An altogether too brief period.

f. Disintegration of uranium—a similar atomic change which takes about 3,000,000 times as long.

The problem is still unsolved.

30. ATMOSPHERE—The atmosphere of the sun is very different from that of the earth in that it is composed mostly of metallic vapors. See 59 b.

31. PARALLAX—Mean 8″.8 of arc. This is the angle subtended at the sun by a radius of the earth as a base-line and when carefully computed at different times of the year provides our astronomical unit, the average being 92,897,425 miles. It may also be determined from a more accurate parallax of a planetoid such as Eros when it comes near the earth as it did in 1931.

32. DISTANCE FROM THE EARTH—Mean 92,897,425 miles as obtained from the parallax above. There are certain corrections to be made such as for eccentricity, perturbations and other variations in the orbit of the earth. At perihelion on January 3, 1933, the distance was 91,343,560 miles, at aphelion on July 2, it was 94,451,290 miles. This distance varies on account of the eccentricity of the earth's orbit and certain perturbations which cause the earth to swing very slightly out of its regular path.

33. DISTANCE FROM THE SUN—This is nil.

34. SOLAR ASPECT—This item is also nil.

35. DIMENSIONS OF ORBIT—The sun's apparent path around the zodiac is not an orbit and thus has no dimensions, but its real path may be a combination of its proper motion of about 397,600,000 miles per year toward Vega and its rotation in the Galaxy at about 5,600,000,000 miles per year. This makes a diameter of about 700,000,000,000,000,000 miles and a circumference of over 2,000,000,000,000,000,000 miles.

36. HELICAL PATH—In the case of the sun this is still a problem for if the proper motion is outward on an arm of the Galaxy and this is combined with the rotation of the Galaxy, it will gradually trace a gigantic geometrical spiral whose increasing radius at present is said to be about 60,000 light years or some 350,000,000,000,000,000 miles. If, however, it is not moving outward, but in some other direction, its radius will change accordingly and its proper motion will combine with its rotation in the Galaxy to produce a different orbital or helical contour.

37. ECCENTRICTY OF ORBIT—With reference to the Solar System, there is none and with reference to the Galaxy, it is as yet unknown.

38. INCLINATION, ORBIT TO ECLIPTIC—There is no such inclination because the sun's apparent path and the ecliptic are in the same plane. The inclination of its proper motion which is probably one component of its real orbit is about 35° from the ecliptic.

39. VELOCITY OF REVOLUTION—In its apparent motion round the ecliptic its apparent speed is the same as the

earth, which is always opposite the sun, but its proper motion toward Vega is 12.6 miles per second while its rotation with the Galaxy is said to be about 180 miles per second.

40. MEAN MONTHLY MOTION—This is the same as the earth, but in its proper motion it is about 33,133,300 miles, while in its galactic rotation it covers about 466,560,000 miles.

41. PERIOD OF REVOLUTION, SIDEREAL—This is only apparent and is due to the revoluton of the earth during the year.

42. PERIOD OF REVOLUTION, SYDODIC—

43. HELIOCENTRIC LONGITUDE—

44. LONGITUDE OF PERIHELION—

45. LINE OF APSIDES—

46. LONGITUDE OF ASCENDING NODE—

47. LINE OF NODES—

48. ARC OF RETROGRADE—

49. PERTURBATIONS IN ORBIT—

50. ELONGATION—

51. CONJUNCTION—

NOTE:—These refer only to the planets, etc., not to the sun.

52. QUADRATURE—

53. OPPOSITION—

54. PHASES—

55. OCCULTATIONS—

56. TRANSITS—

57. SATELLITES—

58. ECLIPSES—Solar eclipses are due to the passing of the moon between the earth and the sun and occur only when the

moon is new and the earth is at a lunar node. This is because the plane of the moon's orbit is tilted about 5°9′ from the ecliptic. Under these conditions an observer in the shadow sees an eclipse. If he is in the umbra the eclipse is total, if in the penumbra it will be partial. Sometimes, on account of the varying distance of the moon caused by the eccentricity of its orbit round the earth, the moon's shadow cannot reach the earth and we see an annular or central eclipse of the sun. The moon's shadow path on the surface of the earth may be as much as 160 miles wide and from 10,000 to 12,000 miles long. The shadow itself is always approximately circular, except during an annular eclipse, when it does not reach the earth. It travels across the earth from west to east at an average of about 2,100 miles per hour, but the earth is rotating at about 1,000 miles an hour in the same direction, thus slowing down the motion. The longest period of an eclipse near the equator is about 8 minutes, but it is briefer at other latitudes. The Saros is a period of 18 years 11 days, which almost equals 19 eclipse years of 346.6 days each and has to do with the recurrence of solar eclipses of which there are from two to five each year. See Moon 58.

59. SPECIAL FEATURES—Under "Markings" we mentioned some of these, but now we shall treat them in further detail.

a. The Corona—This soft pearly envelope of light surrounds the sun on all sides and stretches out into space between 300,000 and 3,000,000 miles, while some of its streamers reach beyond 5,000,000 miles. The corona is highly attenuated and offers almost no resistance to an approaching comet. Its structure is radial and is supposed to be composed of widely scattered dust particles, liquid globules and various gases, with an average density of one dust particle to every 14 cubic yards. It and Bailey's beads are visible during total eclipses and may be photographed without an eclipse.

b. The Chromosphere—This is the rose-coloured envelope and is another layer of gas lying just beneath the corona with a thickness of between 5,000 and 10,000 miles. At total eclipse it appears as a brilliant reddish fringe from whose surface rise the fiery prominences. Some of these are called quiescent and take the form of enormous tree-shaped slow moving bodies of glowing gas in which, with the aid of the spectroscope, we can see the lines of hydrogen, helium and calcium in abundance. Others called eruptive appear like giant fountains of fast moving flame with a spectrum of iron, titanium, barium and sodium and with a rapid radial motion that sometimes drives them into space more than 250,000 miles. Prominences usually occur at sun spots and shoot out at a velocity of 100 to 200 miles per second, but they may arise from any part of the sun's surface.

c. The Reversing Layer—This is also an envelope of gas between 500 and 1,000 miles thick, lying below the chromosphere and acting as an absorbing medium. It gets its name from the fact that in the sun's spectrum there is a series of dark lines in the place of the usual bright ones showing absorption evidently due to the presence of cooler gases in this layer.

d. The Photosphere—This is the visible surface with its rice-grain texture, a name which applies to appearance rather than to nature or actual size. These so-called granules are really between 400 and 600 miles across, and on closer examination, are found to be made up of smaller units about 100 miles in diameter. Nearly 3/4 of the sun's light comes from these very numerous brilliant areas while the spaces between them are duller in appearance and are probably composed of denser gases at lower levels. This whole mottled surface with its spots and flames is the field of solar radiation but the source of the production and projection of its energy lies far within the sun where inconceivable temperatures and pressures indicated in item 29 above keep the great sphere in constant agitation.

e. The Spots—These are the most conspicuous markings, a typical spot appearing like a black hole in the surface. They occur singly and in groups, some being quite irregular and varying in size from mere visibility to great bellowing furnaces more than 200,000 miles across. Their dark tone is only a lesser degree of brightness as compared with the glowing photosphere around them. The spots distribute themselves irregularly a short distance on each side of the sun's equator from latitude 6° to latitude 35°. Their numbers increase and decrease with the years and come to maximum or minimum in a variable period of about 11 years. In 1871 the highest number of spots was 141; in 1884, 75; in 1894, 88; in 1906, 64; in 1918; 105; in 1928, 125. At maximum the spots are from 14 to 45 times as numerous as at minimum. The last maximum occurred in 1928, and as I write we are at the minimum period. Many spots have a slow drift in latitude and longitude as well as violent internal movements which divide them into pairs or groups. Some continue for months and are seen to return with the rotation of the sun while others disappear before they have rounded the sun's limb. In all spots there are magnetic fields due to the vortical motion of particles carrying electric charges which, when aimed at the earth, cause atmospheric disturbances that affect our weather. The magnetic polarity of the spots reverses at every maximum. Interesting graphs are now available which show a close correspondence between the spots and such phenomena as solar prominences, magnetic storms, auroral displays, tree growth, bird migration, quality of crops and market quotations.

60. HABITABILITY—Life as we know it is utterly impossible in such a furnace. It is a star.

NOTE—It may be will to remind those not used to telescopic observation of the sun to have a coloured eye-piece or receive the image of the sun on a piece of white paper held below the eye-piece. When observing the spots day after day they seem to move backward from west to east. This is due to the fact that the spots move round with the sun from east to west, while the earth revolves round the sun in the same direction almost 18 times as fast.

The age of the sun is now estimated at about 8,000,000,000,000 years and its extinction is expected, according to the heat-death theory, in about 15,000,000,000,000 years, but we are of the opinion that it is being constantly renewed.

NOTES

CHAPTER IV.

MERCURY.

1. NAME—Since the ancients never observed this planet except in the morning or the evening sky, they thought there were two of them and therefore, as in the case of Venus, gave it two names. The Egyptians called it Horus and Set, the gods of good and light and of evil and darkness. The Greeks named it Hermes, the sparkling one, while the Romans gave it the names of two brothers: Apollo, god of the day and the light, and Mercury, god of the dark, of thieves, of doctors and of merchants. Later its name was given to quicksilver.

2. MYTH—In classical mythology Mercury was a son of Jupiter and Maia, most beautiful of the seven Pleiades. He presided over the winds, commerce, wrestling and every thing that required dexterity and speed. Later he became the messenger of Jupiter and wore the winged cap and sandals which made his movements so swift and silent.

3. SYMBOL— ☿ This is the caduceus, a rod entwined with two serpents, which when used as a wand would produce sleep.

4. SOUND—In the Music of the Spheres, Mercury was assigned the part of high soprano. Even the great Kepler seems to have thought that the high speed of the planet would cause a sound of high pitch.

5. COLOUR—In the sunlit evening sky Mercury presents a brilliant aspect, but in the morning it shines with a soft yellow light.

6. MARKINGS—These are very difficult to observe on account of the great brilliancy of the planet. Lowell claimed to have seen some irregular marks which he called cracks in the parched hemisphere which is always exposed to the intense heat of the sun, especially during perihelion passage.

7. STELLAR MAGNITUDE—From −1.2 to 1.1 or from about the brightness of Sirius to that of Aldebaran. It is

nevertheless difficult to see on account of its small elongation from the sun, which keeps it in the haze at sunrise or sunset.

8. GREATEST BRILLIANCY—This occurs about 10 days before and after inferior conjunction.

9. ANGULAR DIAMETER—The mean is about 9″ of arc. At inferior conjunction it is 12″.9, at greatest elongation it is 7″, and at superior conjunction it is 4″.5 of arc. This variation is largely due to the great eccentricity of its orbit and its changing distance from the earth. Its angular diameter at mean distance from the earth by which its linear dimensions are obtained is 6″.7 of arc.

10. LINEAR DIMENSIONS—Its equatorial diameter is about 3,030 miles and its circumference around 9,500 miles. These are less than either of the two larger satellites of Jupiter and only one half more than that of our moon.

11. AREA OF SURFACE—About 28,850,000 square miles or about 1/7 of the earth or 1/83,000 of the sun. The surface is probably very mountainous for in a large telescope we can see the uneven edge of the terminator which is the division between the dark and light hemispheres.

12. VOLUME—About 14,566,000,000 cubic miles or about 1/18 of the earth or 1/23,000,000 of the sun. Mercury, unlike the sun, is solid like the other planets.

13. MASS—About 333,000,000,000,000,000,000 tons, or about 1/18 of the earth, but only 1/6,000,000 of the sun. This is very difficult to determine because there is no satellite but it has been estimated from the perturbations caused by the attraction of Venus and certain comets that occasionally pass near.

14. DENSITY—About 4.5 of water, or .85 of the mean density of the earth and over 3 times that of the sun.

15. SURFACE GRAVITY—About .31 of the earth. If one could go to Mercury, his weight would be less than 1/3 of what it is here.

16. FALLING BODIES—During the first second they attain a speed of 8.36 feet per second.

17. VELOCITY OF ESCAPE—Two miles per second. Only a little more than that of the moon. It is the speed a body must attain to free itself from the gravitational attraction of the planet.

18. PERIOD OF ROTATION—About 88 of our days and the same as its period of revolution, so that one hemisphere is always turned toward the sun and its intense heat while the other, except for a libration in longitude, see 26, is always turned away to endless night and extreme cold. This condition is different from that of the moon which, although it keeps one hemisphere toward the earth, nevertheless enjoys sunlight on all sides during each revolution round the earth.

19. VELOCITY OF ROTATION—Since it keeps one hemisphere toward the sun its equatorial velocity will be only about 4 and 1/2 miles per hour. This is very slow and due to the fact that it makes only one rotation during each revolution.

20. DAYS IN ITS YEAR—According to the above Mercury can have only one day in its year, but it is 2112 hours long.

21. MAGNETISM—Since this is a property of rotating bodies and since Mercury rotates but once in 88 days, its magnetic energy must be very weak, unless it is affected directly by the sun's magnetism.

22. OBLATENESS—This is imperceptible even during its transits of the sun and its absence is due to the very slow rotation.

23. DIRECTION OF AXIS—This has not yet been determined, but it is supposed to be perpendicular to its orbit, which has an inclination of 7° from the ecliptic.

24. INCLINATION, EQUATOR TO ORBIT—This is also unknown and may be zero. If there is none and the same hemisphere is always turned toward the sun there will be one unending sun-scorched season which will vary only in proportion to the eccentricity of the orbit.

25. LIBRATION IN LATITUDE—This is a very slow nodding motion of the planet in a north and south direction due to the inclination of its orbit. In the case of Mercury it is difficult to determine.

26. LIBRATION IN LONGITUDE—This is a slow east and west oscillation of the planet which depends on the amount of the eccentricity of the orbit and is caused by the faster speed at perihelion and the slower speed at aphelion. Mercury has the most of all, about 23°.7 each way. Thus on about 3/8 of its surface the sun always shines, on about 3/8 there is constant darkness, and on about 1/4 there is slowly alternating sunlight and shadow requiring of course 88 days.

27. SOLAR RADIATION—Mean 6.7 times that of the earth per unit area. On Mercury it varies greatly; at perihelion it receives more than twice as much as at aphelion which is due to the great eccentricity of the orbit.

28. ALBEDO—Mean .06. This indicates that only a little more than 1/16 of the sunlight received is reflected while the remainder is absorbed by the surface or radiated in the form of heat into outer space. The surface is probably covered with volcanic dust and would appear similar to the moon.

29. TEMPERATURE—The average heat on the sunlit portion is about 780°F. or nearly 14 times what we receive and about 6,000 times more than Neptune. If there are any lakes they may be of molten metal. The permanently dark hemisphere will be exceedingly cold and the portion where light and darkness alternate in 88 days has a gradual increase and decrease of temperature during that period.

30. ATMOSPHERE—There is very little or no atmosphere for no faint ring of light has been seen round its disc during its transits of the sun. No clouds have been discovered and it is altogether likely that the one-time atmosphere has long since been evaporated or absorbed.

31. PARALLAX—The horizontal parallax on January 15, 1933, was 6″.55 and on July 15, 13″.27 of arc. This varies with the orbital positions of both Mercury and the earth. The mean parallax from which the distance is computed is 22″.73 of arc.

32. DISTANCE FROM EARTH—This varies from about 50,000,000 miles at the most favorable inferior conjunction to about 136,000,000 miles at the remotest superior conjunction. Its average distance from the earth is about the same as that of the sun from us.

33. DISTANCE FROM SUN—The mean is about 35,-960,000 miles. At perihelion it is about 28,565,000 miles, and at aphelion 43,355,000 miles. These indicate a large eccentricity of the orbit. Its mean distance is about 1/80 of that of Neptune. It may be well to remark here that the mean distance of a planet from the sun is 1/2 the major axis of its orbit.

34. SOLAR ASPECT—The angular diameter of the sun as seen from Mercury at perihelion is 1°44′ or 3.25 times the diameter of the sun as we see it, while at aphelion it is 1°7′ with a mean of about 1°23′ of arc.

35. DIMENSIONS OF ORBIT—The mean diameter of its theoretical plane orbit is about 71,920,000 miles which would give a circumference of about 225,830,000 miles. This statement however, does not give all the facts so we continue with:

36. HELICAL PATH—The actual path round the sun, as distinguished from its theoretical orbit, is a helix. It is never closed as indicated by the pictures and descriptions usually shown, because of the sun's proper motion through space. In this continuous helical journey along with the sun Mercury traverses, during each revolution of 88 days or one Mercurian year. some 245,320,000 miles, or about 21,490,000 miles more than are given for its theoretical orbit and 149,460,000 miles more than the sun during the same period. To travel these greater distances and thus keep even with the sun requires higher speed than is given for the theoretical orbit. See 39 and Fig. IV.

37. ECCENTRICITY OF ORBIT—.206 The sun is thus out of centre about 7,395,000 miles, which makes a difference of 14,790,000 miles between perihelion and aphelion distances or about 12 times the earth's ratio. It is the cause of the variation of elongation from 16° to 28° of arc and produces two slightly different seasons, as regards temperature, on the sunny side, and also the libration in longitude mentioned above. See 26.

38. INCLINATION, ORBIT TO ECLIPTIC—7° of arc. This is a high inclination and with the large eccentricity provides Mercury with an interesting series of solar and planetary relations. The points of apparent intersection are its nodes.

39. VELOCITY OF REVOLUTION—This varies a good

deal on account of the eccentricity, the mean for the theoretical orbit being about 29.5 miles per second. Since, however, there is no such orbit but rather an open helical path of greater length, its proper average speed is faster at about 32.26 miles per second. At perihelion it speeds up to about 40 miles per second and at aphelion it slows down to about 25 miles per second.

40. MEAN MONTHLY MOTION—In the theoretical orbit it is said to be about 123° of arc or about 77,157,900 miles but in its real helical path it actually covers over 83,817,600 miles.

41. PERIOD OF REVOLUTION, SIDEREAL—About 88 of our days. This is calculated from the synodic period, because it cannot be accurately observed. It is a little less than 1/4 of our year. The word sidereal simply means stellar so that this period is the interval between the moment a planet leaves a star and the moment when it comes round to that star again. It is the planet's year as seen from the sun.

42. PERIOD OF REVOLUTION, SYNODIC—Mean 116 of our days. The word synodic means together on the road and refers to the position of another planet when it is side by side with the earth on the same side of the sun or on the opposite side of the sun from us. It is the interval between two conjunctions of the same kind with the sun as seen from the earth. It varies slightly on account of the eccentricity of the orbit. This period is longer than the sidereal for the inner planets but much shorter for the outer ones.

43. HELIOCENTRIC LONGITUDE—This is the position of a planet measured on the ecliptic from the vernal equinox and as if viewed from the sun. On January 1, 1933, Greenwich civil time it was 205°52′58″ of arc. Heliocentric latitude is the position of a planet measured north or south of the ecliptic and since it is always apparently changing we do not give it but refer the reader to the Observer's Handbook or some good almanac.

44. LONGITUDE OF PERIHELION—This is also heliocentric and is the position of that point in a planet's orbit which is nearest to the sun. It is measured on the ecliptic from the vernal equinox as if viewed from the sun. For Mercury it is about 76°24′47″ of arc. The aphelion point is opposite. The

latitude of these points is governed by the inclination of the orbit to the ecliptic.

45. LINE OF APSIDES—This imaginary line connects the perihelion and aphelion points and is said to be rotating in the direction of revolution about 43″ of arc per century. It is the major axis of the orbit and divides the orbit into equal halves.

46. LONGITUDE OF ASCENDING NODE—This is the position of the apparent intersection of the planet's orbit with the ecliptic where the planet passes from south to north of that line. It is also measured on the ecliptic from the vernal equinox.. For Mercury it as about 47°32′13″ of arc. The descending node is opposite. These apparent intersections have no latitude because they are on the ecliptic.

47. LINE OF NODES—This connects the nodes and divides the orbit with respect to the ecliptic but not into equal parts, because of the amount of eccentricity.

48. ARC OF RETROGRADE—12° of arc. This is the distance of an apparent backward movement which is the result of the combination of the planet's orbital motion with ours. When making the change from direct to retrograde motion the planet is said to be "stationary" for a while. Retrograde motion occurs during inferior conjunctions.

49. PERTURBATIONS IN ORBIT—These are small digressions of the planet from its proper path due to the attraction of other bodies like Venus, or Mercury's own attraction for an occasional comet that comes near.

50. ELONGATION—This is the angular distance of a planet from the sun, as seen by us. On account of Mercury's small orbit it can never draw farther from the sun than between 16° and 28° east or west. Its greatest elongation occurs about 22 days before and after inferior conjunction and about 36 days before and after superior conjunction. It depends on the synodic period.

51. CONJUNCTIONS—For Mercury and Venus thes are of two kinds; inferior and superior, the former when the planet passes between us and the sun, the later when it reaches the

opposite side of the sun from us. In the case of these planets they occur with the sun twice in each synodic revolution. Between inferior and superior the planet is called a morning star and between superior and inferior it is called an evening star, but it is a planet, not a star. The time between two conjunctions of the same kind with the sun is the same as the synodic period. Conjunctions may occur with the moon and the other planets as well as with the sun. See Fig. I.

52. QUADRATURE—This is a position of the moon and the planets outside our orbit. Mercury and Venus have orbits within ours, so cannot reach this position.

53. OPPOSITION—This is also a position of the moon and the planets outside our orbit so Mercury and Venus cannot reach it.

54. PHASES—Mercury shows phases similar to those of the moon. At greatest elongation east and west of the sun it appears as a half disc, as it approaches and leaves inferior conjunction it becomes a crescent, as it approaches and leaves superior conjunction it becomes gibbous. At the former its dark hemisphere is toward us while at the latter it is beyond the sun and hidden in its brilliant rays.

55. OCCULTATIONS—This is the hiding of one heavenly body by another and is possible to many. An occultation of a star by Mercury would be difficult to observe on account of the brightness of the planet, the sun's rays and the haze of our atmosphere. The observation may be made during broad daylight with a large telescope but is still difficult enough.

56. TRANSITS—Transits of the sun can be made by Mercury and Venus only because they alone have orbits within ours and thus often pass between us and the sun. They occur only during inferior conjunctions when the sun is at or near one of the planet's nodes. For Mercury this happens in May and November, but not in every year. On account of the eccentricity of the orbit the May transits occur near aphelion, and are only about half as many as those near perihelion in November. Due to the orbit's inclination the intervals of May transits are about 13 or 46 years, while the November transits may come every 7 or 13 years. This is shown by the repetition of synodic

periods, 22 of which are nearly equal to 7 years, while 41 are nearly equal to 13 years and 145 are just about equal to 46 years. The last transit occurred on November 8, 1927, and the next is due on May 10, 1937. These transits must not be confused with the regular transits by all heavenly bodies across the meridian.

57. SATELLITES—Mercury has evidently no lunar attendant although many determined efforts have been made to discover one. Despairing of the direct observational method, some mathematicians have made extended calculations but with no result.

58. ECLIPSES—The transits mentioned above are of the nature of eclipses of the sun, but when Mercury or Venus pass between us and the sun they appear so small that these passages are spoken of as transits. It would be possible for Mercury to eclipse Venus or vice versa, if they should arrive at the proper orbital relation to each other and us.

59. SPECIAL FEATURES—Mercury has several of these; it is nearest to the sun, receives most radiation per unit area, has the least mass and volume, has the highest speed of revolution, has the least elongation, is seldom seen, always keeps the same hemisphere toward the sun, has no atmosphere, no water and no moon.

60. HABITABILITY—From all that has been said above we cannot think of life on this planet.

NOTE:—Mercury may be seen best in northern latitudes as an evening star in spring a short time after sunset, and as a morning star in the fall a short time before sunrise. See Observer's Handbook or almanac for the times and positions.

CHAPTER V.

VENUS.

1. NAME—The Babylonians called it Ishtar and made the first recorded observation in 685 B.C., on a clay tablet, now in the British Museum. Among the Greeks it had four names: Phosphorus or Lucifer in the morning, and Hesperus or Callistos in the evening. The Romans assigned her several names: the two most used were Venus the beautiful and Vesper the evening star. For many years in many lands it has been called the Shepherd's star or the Star of Bethlehem, but there is no adequate astronomical connection.

2. MYTH—The stories about Venus are very numerous and badly mixed up. The Romans said that she was the daughter of Jupiter and Dione and that her father gave her to Vulcan in marriage. She was the goddess of vegetation, fruit, flowers, love and beauty. Her little son Cupid later became the god of love and his Greek name Eros has been given to a planetoid.

3. SYMBOL—♀ A circle with a handle to represent the mirror with which she is said to have constantly admired her own beauty.

4. SOUND—In the Music of the Spheres she was assigned the alto part.

5. COLOUR—A glistening yellowish white, so dazzling that it is very difficult to observe the disc with any degree of satisfaction, except at its greatest elongation through a haze.

6. MARKINGS—In spite of its glare some astronomers have seen a few irregular grayish areas that were so inconstant that the drawings of different men do not agree, but the best recent photographs show a cloud-banded surface.

7. STELLAR MAGNITUDE—This varies from −3.3 to −4.3, according to its phase and its distance from us. Under very favorable conditions it is 50 times as bright as Sirius and 10 times more brilliant than Jupiter.

8. GREATEST BRILLIANCY—This occurs about 36 and 1/4 days before and after inferior conjunction at which time its phase is like the moon's, 5 days old. There is also a special maximum every 8 years, the next will occur in 1937.

9. ANGULAR DIAMETER—Its mean is 38″ of arc. At inferior conjunction it is 67″ and at superior conjunction it is only 10″. As it approaches us it seems to grow from a tiny disc to a large thin crescent about 6 times as broad. Its angular diameter at mean distance from the earth by which its linear dimensions are obtained is about 17″ of arc.

10. LINEAR DIMENSIONS—The equatorial diameter is close to 7650 miles and on account of its slow rotation its polar diameter will be about the same. Its equatorial circumference is about 24,100 miles. In many ways it is similar to the earth.

11. AREA OF SURFACE—About 184,000,000 square miles or .94 of the earth and 1/12,700 of the sun. It must be remembered that we have no knowledge of the actual surface, but only of the dense cloud-envelope that surrounds it.

12. VOLUME—About 235,300,000,000 cubic miles, or about .91 of the earth and 1/1,386,000 of the sun.

13. MASS—About 4,900,000,000,000,000,000,000 tons or .82 of the earth and 1/480,000 of the sun. This is difficult to determine because there is no satellite, but it has been estimated from the perturbations caused by Mercury and the earth.

14. DENSITY—Average 4.86 of water or .88 of the earth's average and over 4 times that of the sun. This is quite similar to Mercury.

15. SURFACE GRAVITY—About .85 of the earth so that an object that weighs 100 pounds here would weigh only 85 pounds there.

16. FALLING BODIES—During the first second they attain a speed of 13.81 feet per second.

17. VELOCITY OF ESCAPE—6.51 miles per second. This is 3 and 1/2 times that of Mercury and nearly equal to that of the earth.

18. PERIOD OF ROTATION—Possibly 225 of our days but this is not yet determined. At one time it was thought to be about 24 hours like the earth, but later some said it rotated in 3 days, while today others think it may take 4 or 5 weeks. Who will settle it?

19. VELOCITY OF ROTATION—This must wait until someone discovers its period of rotation. If, however, it is like Mercury and rotates only once during each revolution, its equatorial rate will be about 107 miles per day or quite similar to that of Mercury.

20. DAYS IN ITS YEAR—If Venus rotates only once during each revolution it has only one day in its year but that day is 5400 hours long.

21. MAGNETISM—Venus should have weak magnetic currents if these are due to rotation, but she receives solar magnetic energy into a dense atmosphere, which should cause great disturbances.

22. OBLATENESS—There seems to be very little if any polar flattening or equatorial bulge, due no doubt to the slow rotation.

23. DIRECTION OF AXIS—As yet unknown. Some have thought that it is in the same plane as its orbit, others that it is perpendicular to it.

24. INCLINATION, EQUATOR TO ORBIT—This, like the direction of the axis, is still in doubt, the estimates ranging between 0° and 90° of arc.

25. LIBRATION IN LATITUDE—The inclination of the orbit to the ecliptic is so small, as we shall see later, that any north and south noddings are imperceptible.

26. LIBRATION IN LONGITUDE—The small eccentricity of the orbit, as we shall see later, and the consequent slight difference in the orbital speed allows for only a very narrow librating zone on the surface which will have very slowly alternating light and darkness during each rotation or Venusian year-day.

27. SOLAR RADIATION—On the sunny hemisphere Venus receives 1.91 times what we receive. Unlike Mercury

there is the heavily cloud-laden atmosphere which probably disperses the sunlight so that conditions on that side may be tropical.

28. ALBEDO—From .59 to .76 with a mean of about .6, or nearly 10 times that of Mercury. This of course is due to the cloud mantle which has been shown by experiment to be an excellent reflector of sunlight.

29. TEMPERATURE—Since the amount of radiation is about twice as much as we receive, it is thought that the temperature may be perhaps twice as high as ours, at least on the sunny side, but this has been very difficult to measure on account of the clouds which cover the surface at all times.

30. ATMOSPHERE—This is thought to be about twice as dense as ours and about 250 miles deep. Unlike Mercury and the moon, Venus has gravitational attraction enough to retain its atmosphere and its presence is proved by the distinct fringe of light which is visible round its disc during its transits of the sun. It is also apparent at inferior conjunctions when the illuminated edge projects beyond the horns of the crescent as also by the gradual immersion of the stars it occults.

31. PARALLAX—The horizontal parallax on January 15, 1933, was 5″.83 and on July 15, 5″.70 of arc. This is always changing with the orbital positions of Venus and the earth. The mean parallax from which distance is computed is 12″.22 of arc.

32. DISTANCE FROM EARTH—This varies from about 25,700,000 miles at inferior conjunction to 160,100,000 miles at superior conjunction. It is about 6 times as far from us at superior as it is at inferior conjunction and its mean distance is about 93,000,000 miles.

33. DISTANCE FROM SUN—The mean is 66,886,000 miles. At perihelion it is about 66,416,000 miles and at aphelion 67,356,000 miles. This means a very small eccentricity of the orbit.

34. SOLAR ASPECT—The mean angular diameter of the sun as seen from Venus is about 44′20″ of arc, or nearly 1 and 1/2 times as big as we see it.

35. DIMENSIONS OF ORBIT—The mean diameter of its

theoretical orbit is about 133,770,000 miles from which we derive a circumference of 420,400,000 miles. But, as we have previously noted, the orbits are really helical.

36. HELICAL PATH—The real path round and with the sun is an open helix far different from the theoretical orbit. It cannot be closed because of the sun's motion through space. In this continuous helical journey along with the sun Venus traverses, during each revolution of 225 days or one Venusian year, some 486,430,000 miles or about 65,920,000 miles more than are given for its theoretical orbit and 231,850,000 miles more than the sun during the same period. To travel so much farther it must go much faster than is given for its theoretical orbit. See 39 and Fig. IV.

37. ECCENTRICITY OF ORBIT—.007. The sun is thus out of centre only about 470,000 miles, so that the difference between perihelion and aphelion distances is only 940,000 miles. When this orbit is drawn to scale its departure from a circle cannot be distinguished by the unaided eye. This keeps any librations very small and makes the sunlit hemisphere endure a single almost unvarying season.

38. INCLINATION, ORBIT TO ECLIPTIC—3°24′ of arc. This slight angle will accentuate the unvarying quality of the season especially if the axis is perpendicular to the orbit. If, however, one wished to escape the tropical heat, he might fly round to the cold side and enjoy the constant winter sports. The points of apparent intersection of the orbit and ecliptic are the nodes.

39. VELOCITY OF REVOLUTION—Since the orbit is nearly circular the speed cannot vary much and the mean for the theoretical orbit is 21.65 miles per second, but its helical speed is 25 miles per second.

40. MEAN MONTHLY MOTION—In the theoretical orbit it is said to be about 48° of arc or about 56,053,300 miles but in its real helical path it actually covers over 64,857,000 miles.

41. PERIOD OF REVOLUTION, SIDEREAL—About 225 of our days or nearly 7 and 1/2 months. You will remember that sidereal means stellar and refers to the period between the

apparent visits of the planet to any specified star in the zodiac. It is the planet's year as if seen from the sun. Venus makes about 13 revolutions to 8 of our earth.

42. PERIOD OF REVOLUTION, SYNODIC—Mean about 584 of our days or 1 year and 7 months. You will remember that synodic means together on the road and refers to the position of another planet when it is side by side with the earth on the same side of the sun or on the opposite side of the sun from us. It is the interval between two conjunctions of the same kind with the sun as seen from the earth. This period is longer than the sidereal for the inner planets but much shorter for the outer ones.

43. HELIOCENTRIC LONGITUDE—On January 1, 1933, Greenwich civil time it was 215°19′59″ of arc. Heliocentric latitude is a changing quantity so we do not give it. See Mercury 43.

44. LONGITUDE OF PERIHELION—For Venus it is 130°37′42″ of arc. Aphelion is opposite. The latitude of each is governed by the inclination of the orbit to the ecliptic. See Mercury 44.

45. LINE OF APSIDES—This imaginary line joins the perihelion and aphelion points and is the major axis and divides the orbit in equal parts.

46. LONGITUDE OF ASCENDING NODE—76°4′36″ of arc. The descending node is opposite. These apparent intersections have no latitude because they are on the ecliptic. See Mercury 46.

47. LINE OF NODES—This imaginary line connects the nodes and divides the orbit with respect to the ecliptic, but not into equal parts because of the eccentricity.

48. ARC OF RETROGRADE—16° of arc. This is due to the combined motions of the earth and the planet and seems to be a backward motion but is only apparent. When making the apparent change from direct to retrograde motion the planet is said to be "stationary" for a while. Retrograde motion occurs during inferior conjunctions.

49. PERTURBATIONS IN ORBIT—These are very slight because of the near equality of the masses of Venus and the earth. Any effect that Mercury may have especially during its aphelion passage must also be slight because of its small mass.

50. ELONGATION—This is the angular distance of Venus from the sun as seen by us. It depends on the synodic period and thus its position varies with ours. The orbit of Venus being within ours its maximum is only 48° of arc east or west of the sun. Her greatest elongation occurs about 72 days before and after inferior conjunction and 220 days before and after superior conjunction.

51. CONJUNCTIONS—As with Mercury these are both inferior and superior and they occur twice during each synodic period. See Mercury 51.

52. QUADRATURE—Venus cannot reach this position because its orbit is within ours.

53. OPPOSITION—This is a configuration of planets whose orbits are outside ours so Venus cannot reach it.

54. PHASES—These are very similar to those of Mercury and the description is the same. See Mercury 54.

55. OCCULTATIONS—In the case of Venus these are very difficult to observe because of its great brilliancy, but may be seen through a haze with a telescope.

56. TRANSITS—Transits of the sun by Venus like Mercury occur only during inferior conjunctions when the sun is apparently near one of the planet's nodes. For Venus they occur in June and December but they seldom happen because of the inclination of the orbit. Indeed they occur only 4 times in 243 years. If we start with a June transit the next will be in 8 years, then in 105.5 years, then in 8 years again and then in 121.5 years. The last took place on December 6, 1882, and the next will be on June 8, 2004.

57. SATELLITES—Like Mercury it seems that Venus is without a moon. Many have undertaken the task of discovery both by direct observation and mathematical deduction, but without success. If you find one be sure and call it Cupid.

58. ECLIPSES—As in the case of Mercury the only eclipses are those very partial ones caused by its occasional transits of the sun, but the disc of the planet, as it passes between us and the sun, is so small that this relation cannot be properly called an eclipse. Under the proper conditions it is possible for Venus to eclipse Mercury and vice versa but it will be very seldom.

59. SPECIAL FEATURES—The outstanding items regarding Venus are: an invisible surface, one hemisphere probably always turned toward the sun, similar to the earth in many respects but has only one day in its year, possesses the greatest brilliancy and the highest albedo, has the least eccentricity and comes nearest to the earth, has no moon but may be the abode of some forms of life.

60. HABITABILITY—From much of the foregoing information it seems quite reasonable to think that here is a planet fit for human habitation, but the problem is far from being settled.

NOTE:—Let us all keep constant watch for the most recent information regarding some of these items because when someone discovers the rotation period a number of other items will have to be revised to agree with it.

Observations are best made with a telescope in the evening through a haze or during the day without a haze.

CHAPTER VI.

TELLUS, THE EARTH.

1. NAME—The Greek name for the land portion was Ge or Gaea, and for the water portion Poseidon. The Romans called the land Tellus or Terra and the water Neptune. In old English it was Ear meaning plow, from which we have the name Earth, because much of the land surface is earable or, as we say, arable.

2. MYTH—In Greek mythology Gaea was the wife of Uranus and mother of the Titans including the greedy Cronos and Rhea and grandmother of Zeus and Poseidon.

3. SYMBOL—⊕ A circle with its diameters which probably represent the main circles of a system of co-ordinates.

4. SOUND—In the Music of the Spheres there was no part for the earth, because the ancients thought it was the centre of the universe and on that account immovable and soundless. Later Kepler suggested the role of contralto.

5. COLOUR—Viewed from nearby planets ours would display varied areas of yellow and brown for the land and black for the sea while the clouds would appear white, pink and gray.

6. MARKINGS—The colours would define the markings while their boundaries would roughly coincide with the continents and oceans.

7. STELLAR MAGNITUDE—To the nearer celestial observers our planet would appear very brilliant, especially at closest approach. We know that the earth shines because light from it is reflected to the moon and then returned to us by its dark side. This is the so-called "earth shine" and is spoken of as "the old moon in the new moon's arms."

8. GREATEST BRILLIANCY—This would be for observers on other planets when those inside our orbit overtake us or we overtake those outside of us.

9. ANGULAR DIAMETER—As seen from Venus the mean angle would be about 39″ and from Mars about 26″ of arc.

10. LINEAR DIMENSIONS—As repeatedly measured by different methods the mean diameter is 7,917 miles, the polar is close to 7,900 miles and the equatorial 7,926 miles. This would give a mean circumference of 24,880 miles, a polar of 24,860 miles and an equatorial of 24,900 miles. It would take 11,700 such worlds placed side by side to reach between us and the sun.

11. AREA OF SURFACE—197,000,000 square miles of which 56,000,000 are land and 141,000,000 are water. This amount of water, if spread out could cover the earth 1 and 1/2 miles deep. The area is a little less than 1/12,000 of the sun.

12. VOLUME—260,000,000,000 cubic miles so it would require about 1,300,000 earths to equal the size of the sun. The volume of the water is about 300,000,000 cubic miles. The structure of our earth from most recent estimates is a central core of solid nickel and iron about 3,000 miles in diameter surrounded by a spherical layer of heavy rock richly impregnated with nickel and iron about 1,400 miles thick. Over this is a second of volcanic basalt about 1,000 miles thick covered in turn by a layer of granite on an average about 35 miles thick. This last layer has been greatly broken, shifted and eroded as well as partially covered by sedimentary rocks.

13.—MASS—This is somewhat more than 6,000,000,000,000,000,000,000 tons or about 1/333,000 of the sun. It has been measured by a number of interesting methods such as Maskelyne's mountain method, Cavendish's torsion balance, Airy's mine experiment and recently in the Bureau of Standards at Washington. It is the unit of mass. The water weighs about 1,180,000,000,000 tons and the air weighs about 6,000,000,000,000,000 tons or 1/1,000,000 of the whole.

14. DENSITY—Average for the entire earth 5.6 times that of water. At the surface it is about 2.3 times water while the interior is said to be between 8 and 15 times water.

15. SURFACE GRAVITY—This is the earth's gravitational attraction for anything on its surface and is measured by a great variety of instruments called weigh scales. It differs

slightly at different locations according to latitude and rotation as well as altitude and oblateness.

16. FALLING BODIES—During the first second they attain a velocity of 16.07 feet per second.

17. VELOCITY OF ESCAPE—6.95 miles per second. This must be taken into consideration when the matter of sending rockets to the moon is discussed.

18. PERIOD OF ROTATION—23 hrs. 56 min. 4 sec. This, as we all know, produces our days and nights, which vary in length at different times of the year on account of the inclination of the earth's equator to the plane of its orbit, the ecliptic. The proofs of rotation are numerous, the more important being the shape of the earth, the eastward drift of falling bodies, the deviation of air currents, the analogy to other planets that rotate, the various pendulum experiments, the decrease of gravity from the equator to the poles and the unique action of the gyroscope. It has been estimated that the period of rotation was once as brief as 3 or 4 hours and that this caused the release from our ocean basins of the matter now called the moon. The question is, will it ever come back? See Appendix, "Diana's Return."

19. VELOCITY OF ROTATION—At the equator it is 1,440 feet per second, or 1,040 miles per hour and 24,900 miles per day. At the latitude of Philadelphia the speed is about 800 miles per hour, while at the tip of Greenland it is only 500. It is said that the tides retard the rotation about one second in 500,000 years.

20. DAYS IN ITS YEAR—365 days, 6 hours 9 minutes, 9.5 seconds of mean solar time. See 41.

21. MAGNETISM—Our planet is found to be an enormous magnet and is estimated to possess a power equal to 8,500,000,000 one pound iron bars magnetized to saturation. Its average intensity, however, is only 1/10,000 of highly magnetized steel. Its north magnetic pole is situated in northern Canada at about 71° north latitude and 97° west longitude, about 1,200 miles south of the axial pole, while the south magnetic pole is at 73° south latitude and 155° east longitude, almost but not quite opposite. This energy is greatly disturbed during sun spot maxima.

22. OBLATENESS—.00337 or 1/297. This fraction amounts to about 26 miles. Oblateness is proved by accurate measurements of the length of a degree of latitude on the earth's surface. At the equator it is 68.71 miles while at the poles it is 69.40 miles with an average of 69 miles. This near sphericity is fully proved by the fact that the direction of the plumb line and consequently the plane of the horizon changes in direct proportion to the distance an observer travels on the earth's surface and may be tested in any direction by careful surveys while the direction of the plumb line may be determined by observations of the stars. The equatorial bulge produced by rotation is attracted by the sun and moon to cause the precession of the equinoxes at about 50″ of arc per year. Added to this there is another small slow wabbling motion of the earth's axis called Nutation which makes the poles describe a wavy course during its revolution.

23. DIRECTION OF AXIS—At the present time it is toward Alpha Ursae Minoris (Polaris) although the true celestial pole is some distance from it. During the past 4,900 years the direction has been changing from Alpha Draconis (Thuban) around to its present position and it will continue in that direction for about 200 years more. Then it will depart on its slow journey toward Alpha Cephei (Alderamin) and thence toward Alpha Lyrae (Vega). It will take about 12,000 years to reach the vicinity of Vega and 25,800 years to complete the circle back to its present position. This is due to the precession of the equinoxes mentioned above.

24. INCLINATION, EQUATOR TO ORBIT—23°28′ of arc. This is the cause of our varied seasons. In spring there are about 93 days, in summer about 93.5 days, in autumn about 90 days and in winter about 89 days. It is interesting to know that during our midsummer the north polar region receives 1/4 more solar radiation per unit area than does the equator. See Fig. VIII.

25. LIBRATION IN LATITUDE—Since there is no inclination of the orbit to the ecliptic there are no important north and south noddings.

26. LIBRATION IN LONGITUDE—Since the eccentricity is so small there are no appreciable east and west oscillations.

27. SOLAR RADIATION—Out of the total radiation emitted by the sun the earth stops and receives only a small beam about 8,000 miles in cross section which is nearly 1/2,200,000,000. This is about 230,000,000,000,000 horse power. In candle power it would be about 3,500,000,000,000,000,000 or something like 160 tons of light per year. This is about 1/10 of the total received by the members of the Solar System.

28. ALBEDO—As seen from nearby planets this would vary greatly and in proportion to the amount of cloud present in our atmosphere. Its average is said to be about .2.

29 TEMPERATURE—Due to the sun's heat the average is about 56°F. but the earth itself still possesses much internal heat which, because of increased pressure, rises to thousands of degrees at the centre. This, however, is not enough to prevent the earth's surface from becoming a frigid waste if the sun's heat were withdrawn for a short time. The maximum of solar heat on the earth occurs about August 1 and the minimum about February 1. This produces what is called the lag of the seasons. The pressure per square inch at the centre is said to be about 22,500 tons.

30. ATMOSPHERE—The density of the air at the earth's surface averages about 1/773 of water. Its height is indefinite because its density decreases as we ascend. Calculated from the duration of twilight, which ceases when the sun reaches 18° below the horizon, it is about 50 miles high but from other observations, such as the aurora, it is known to be more than 100 miles. It is then very rare. Its total weight is about 6,000,000,000,000,000 tons or 1/1,000,000 of the entire earth's mass. Its pressure at sea level is about 15 pounds per square inch. Connected with the atmosphere are such phenomena as the refraction and dispersion of light, the aurora north and south, the twilight, the wonders of sunrise and sunset and a great variety of storms. A rainfall of 34 inches per year amounts to more than 2,000,000 tons per square mile and a single rain of one inch leaves about 60,000 tons on each square mile.

31. PARALLAX—Since we live here there is none for us but only for observers on other planets.

32. DISTANCE FROM EARTH—This also is nil.

33. DISTANCE FROM SUN—Mean about 92,897,425 miles. At perihelion on January 3, 1933, it was 91,343,560 miles, while at aphelion on July 2, it was 94,451,290 miles. The variation is due, of course, to the eccentricity of the orbit.

34. SOLAR ASPECT—This is common knowledge to us all. In angular measure the apparent diameter is 32′4″ of arc. See Sun 9.

35. DIMENSIONS OF ORBIT—The mean diameter of its theoretical orbit is nearly 186,000,000 miles from which we have a circumference of about 584,000,000 miles. But again we must remember that these are fictitious distances because the true path is helical.

36. HELICAL PATH—The earth's real path with the sun is a quite open helix in which the earth traverses, during each revolution of 1 Tellurian year, some 706,500,000 miles or about 122,600,000 miles more than are given for its theoretical orbit and 308,900,000 miles more than the sun during the same period. See 39 and Fig. IV.

37. ECCENTRICITY OF ORBIT—.0167. The sun is thus out of centre about 1,500,000 miles which makes a difference of 3,000,000 miles between perihelion and aphelion distances. This, like that of Venus, is quite small and indicates an almost circular path but helical.

38. INCLINATION, ORBIT TO ECLIPTIC—There is none since both orbit and ecliptic are in the same plane. The earth is always opposite the sun.

39. VELOCITY OF REVOLUTION—This does not vary much on account of the slight eccentricity of the orbit, the mean for the theoretical orbit being about 18.5 miles per second, while for the helical path it is about 22 miles per second or 1,900,800 miles per day which is 202,400 miles more than is given for the theoretical orbit.

40. MEAN MONTHLY MOTION—In the theoretical orbit it is said to be about 30° of arc or about 48,666,700 miles, but in its real helical path it actually covers over 58,875,000 miles.

41. PERIOD OF REVOLUTION, SIDEREAL—365 days, 6 hours, 9 minutes, 9.5 seconds of mean solar time. The tropical year or year of the seasons is slightly less or 365 days, 5 hours, 48 minutes, 46 seconds, while the anomalistic year, which is the time between two successive perihelion passages, is 365 days, 6 hours, 13 minutes, 53 seconds. There are about 186 days between vernal and autumnal equinoxes, and 179 days between autumnal and vernal equinoxes. The earth's revolution round the sun is proved by the annual variation in the radial velocities of stars, by the annual parallactic displacement of stars and by the aberration of light.

42. PERIOD OF REVOLUTION, SYNODIC—This is only as seen from other planets.

43. HELIOCENTRIC LONGITUDE—On January 1, 1933, Greenwich civil time it was 100°8′42″.9 of arc. Heliocentric latitude is not given, because it is always changing. See Mercury 43.

44. LONGITUDE OF PERIHELION—About 101°47′17″ of arc. Aphelion, of course, is opposite. The latitude of each is governed by the inclination of the orbit to the ecliptic. See Mercury 44.

45. LINE OF APSIDES—This imaginary line joins the points of perihelion and aphelion and is said to rotate in about 108,000 years. It is the major axis of the orbit and divides it into two equal parts.

46. LONGITUDE OF ASCENDING NODE—There are no nodes because the orbit lies in the plane of the ecliptic.

47. LINE OF NODES—For the reason above there is no line of nodes for the earth.

48. ARC OF RETROGRADE—This is another item that has to do only with the other planets.

49. PERTURBATIONS IN ORBIT—These are of two kinds: secular, meaning age-long; and periodic, meaning occasional. The former are slight variations in the shape of the orbit over long periods of time caused by the attraction of the moon, Venus and the sun. The latter are slight temporary variations

in the orbital position of the earth due to the same attraction. The more important secular perturbations are: the decrease of the angle of inclination of the orbit which requires about 15,000 years, the decrease in the ratio of eccentricity for 24,000 years more until it becomes .003 and then its increase for 40,000 years until it becomes .02, the precession of the equinoxes which requires about 25,000 years, and the rotation of the line of apsides which will carry the points of perihelion and aphelion round their path in about 108,000 years. The periodic perturbations are very small and unimportant because the masses of the disturbing bodies almost balance that of the earth.

50. ELONGATION—

51. CONJUNCTION—

52. QUADRATURE—

53. OPPOSTION—

54. PHASES—

55. OCCULTATIONS—

56. TRANSITS—

NOTE:—These refer only to the other planets, etc. not to the earth.

57. SATELLITES—The earth is blessed with the best and most useful moon we know and it is important enough to deserve a chapter for itself.

58. ECLIPSES—We do not speak of eclipses of the earth but eclipses of the sun, except central ones, are very small partial eclipses of the earth as seen from the sun.

59. SPECIAL FEATURES—The most outstanding astronomical significance of the earth is the fact that it is our great observatory for the study of the universe. It also provides the unit of measure for various items. Besides these it is the theatre of the continual and continuous pageant of human activities. It is the only planet whose age may be fairly estimated from its structure at about 2,000,000,000 years where life has flourished for possibly 2,000,000 years and human life in particular, perhaps 300,000 years.

60. HABITABILITY—There is no question about the possibility of life on this planet since we find its population to be about 2,000,000,000 human beings.

NOTE:—The earth has then at least a dozen different motions, the knowledge of which is very interesting. See 18, 22, 24, 36, 41, 44, 49 as well as its rotation with the sun round the Galaxy at 180 miles per second, and its recession along with the sun and stars in the direction of expansion. Can you construct a wire model of it all?

CHAPTER VII.

DIANA, THE MOON.

1. NAME—Among the Egyptians and Babylonians it was a male divinity. The former called it Aah and Thoth, while the latter named it Nannar and Sin, the light giver and dispenser of wisdom. The Greeks somehow changed it to a goddess called Selene, meaning brightness and Mene meaning month. She was a daughter of Hyperion and Theia and sister of Helios the sun. In later times they called her Artemis and Phoebe goddess of the moon and daughter of Zeus and Leto. The Romans named it Diana, Luna and Phoebe, the radiant one, daughter of Jupiter and Latona and sister of Phoebus Apollo.

2. MYTH—The most popular story tells how the huntress Diana, goddess of the chase and provider of sustenance for all living creatures, once fell in love with the beautiful sleeping shepherd Endymion, who was gifted with eternal youth but overcome by continual sleep. While he slept she lovingly tended his flocks and herds. The worship of Diana was widespread in the Roman Empire and her remarkable temple at Ephesus was considered one of the seven wonders of the ancient world.

3. SYMBOL—☽ A crescent is the usual symbol, but the half, the full, and the dark faces are used for the quarter, the full, and the new phases respectively.

4. SOUND—In the Music of the Spheres the moon's part, according to Cicero was bass.

5. COLOUR—This varies greatly and ranges from silvery white to deep red according to its position with reference to the sun, its phase and the condition and density of our atmosphere.

6. MARKINGS—Observed with the unaided eye the surface shows large shaded and smaller brilliant areas. The man in the moon is an optical illusion not visible in a telescope. The ancients said he was put there because he gathered wood on Sunday. The woman in the moon, the rabbit of the Hindus and the monkey of the Chinese are all in the same class. Through a

telescope they appear like old sea basins from which the water has disappeared. One may also see a number of mountain ranges and many roughly circular craters. The terminator is sharp because there is no atmosphere to provide twilight as on the earth.

7. STELLAR MAGNITUDE—At full it is −12.55 or about 1/2 that of the sun. Naturally it is less at the other phases.

8. GREATEST BRILLIANCY—It sheds most light at full phase but it seems most brilliant at first quarter.

9. ANGULAR DIAMETER—Mean 31′14″ of arc. At perigee it is 32′56″ and at apogee 29′31″ of arc. We have all noticed that it seems smaller and clearer on the meridian than it does at the horizon. This is due to the fact that when we look at it high in the sky we observe it through much less thickness of atmosphere and about 4,000 miles less distance. Its angular diameter at mean distance from the earth is just about the same as the mean above or 1874″ of arc.

10. LINEAR DIMENSIONS—Its actual diameter as obtained from the above is close to 2,163 miles or a little more than 1/4 of the earth's while its circumference is about 6,795 miles.

11. AREA OF SURFACE—About 14,700,000 square miles which is about .077 or 1/13 of the earth's. This is nearly the same as the land surface of our western hemisphere.

12. VOLUME—The cubical content is about 5,298,000,000 cubic miles or 1/49 of the earth. It would take 64,000,000 moons to equal the size of the sun. If this matter could be evenly spread over the earth it would form a layer 26 miles deep.

13. MASS—This is about 1/81 of the earth and something like 75,000,000,000,000,000,000 tons or about 1/30,000,000 of the sun. The centre of gravity of the earth-moon system is within the earth's surface about 1,000 miles.

14. DENSITY—About 3.39 times that of water or .6 of the earth's average and a little less than 2.5 times the sun.

15. SURFACE GRAVITY—About 1/6 of the earth's. A person weighing 120 pounds here would weigh only 20 pounds

there and one could jump 6 times as high and 6 times as far as he can here. This accounts for the unusual height of the mountains and the great diameter of the craters.

16. FALLING BODIES—During the first second these objects attain a speed of only 2.6 feet per second. This is about 1/6 of the earth's rate.

17. VELOCITY OF ESCAPE—About 1.5 miles per second or less than Mercury.

18. PERIOD OF ROTATION—27 days, 7 hours, 43 minutes, 11.5 seconds. This is the same as the sidereal period and thus the moon always presents the same hemisphere to us. This is proved by the fact that the markings are always the same. There are some interesting librations, however, which help us to see a little more than half the surface. See 25 and 26.

19. VELOCITY OF ROTATION—This is unusually slow, there being only one rotation in about 28 days. The equatorial speed which is constant is about 10 miles per hour, while the orbital speed varies on account of the eccentricity and a great variety of perturbations. See 49.

20. DAYS IN ITS YEAR—Its year, like ours in length, is nevertheless composed of only 12.37 lunar days which are also its months.

21. MAGNETISM—This characteristic is unimportant on account of the slow rotation. The magnetic poles are unknown to the writer.

22. OBLATENESS—There seems to be no appreciable polar flattening or equatorial bulge and this is no doubt due to the slow rotation.

23. DIRECTION OF AXIS—Since the inclination of the moon's equator to the ecliptic is 1°32′ its poles point in almost the same direction as those of the ecliptic, toward Draco and opposite.

24. INCLINATION, EQUATOR TO ORBIT—6°41′ of arc which is the sum of the angle of the equator to the ecliptic 1°32′ and the angle of the orbit to the ecliptic 5°9′ of arc.

25. LIBRATION IN LATITUDE—These are slow north and south noddings of the moon due to the inclination of its equator to its orbit, so that during each revolution its poles are gradually tilted each way until at maximum we are able to see a little more than 6° beyond them, thus adding to the amount of visible surface.

26. LIBRATION IN LONGITUDE—These are slow east and west oscillations of the moon due to the combination of the constant speed of rotation and the variable speed of revolution so that we can see a little more of each edge, again adding to the amount of surface visible. Besides these there is a small diurnal libration caused by the earth's rotation. Altogether it is possible to observe about 60% of the moon's surface or an area about the size of North America, while the remaining 40% or about the area of South America is always hidden from our view but not from the sun.

27. SOLAR RADIATION—The moon receives about the same amount of light and heat, per unit area, as does the earth, the average per month being about 1/1,000,000 of what we receive from the sun; in other words, we receive as much light from the sun in 13 seconds as we get from the moon in a whole year. Even at full phase it reflects to us only about 1/600,000 of what the sun sends us. If the sky were filled with full moons they could give us only 1/8 of the amount we receive from the sun and yet that would be 100,000 times the amount sent us by the stars.

28. ALBEDO—Mean .07. This makes our moon an ideal satellite and caused the ancient Persians to call it the mirror of the earth. Its surface, like that of Mercury, is probably covered with volcanic dust.

29. TEMPERATURE—The moon has evidently lost its atmosphere and its internal heat so that the sun is now its only source of warmth. During its two weeks cloudless day it receives so much heat that its temperature rises to about 115°C. or 230°F. while during its two weeks pitch black night it drops to about −80°C. or −112°F. On the dark side it has been found as low as −240°F. During the brief period of total eclipse it has been known to fall over 300 degrees to as low as −180°F. The amount of heat sent us is almost imperceptible.

30. ATMOSPHERE—There is no known air envelope surrounding the moon and no cloud or fog has ever been seen. Without air or water there can be no wind or cloud and therefore no vegetation or erosion. No definite change of surface has ever been recorded.

31. PARALLAX—The mean horizontal parallax from which the distance is computed is 57′3″ or 3,423″ of arc.

32. DISTANCE FROM EARTH—Mean 238,850 miles. At perigee it is 225,700 miles and at apogee about 253,000 miles. At perigee the distance from surface to surface is about 220,000 miles. Should a volcanic outburst occur on the moon we could see the flare in slightly more than a second but the noise would require nearly two weeks to reach us. We must remember, however, that there is no medium to carry the sound.

33. DISTANCE FROM SUN—The mean is, of course, about the same as that of the earth but, on account of its revolution round the earth, the distance varies. It also varies because of their revolution round their mutual centre of gravity within the earth. Altogether the moon suffers many causes of variation in its solar distance.

34. SOLAR ASPECT—Because of the lack of atmosphere on the moon the sun would appear much smaller and clearer than it does to us. The sky from there would appear black.

35. DIMENSIONS OF ORBIT—The mean diameter of its theoretical earth orbit is about 478,000 miles and its circumference about 1,442,000 miles. The mean diameter of the theoretical sun orbit as well as its circumference are similar to the earth's, but since the moon revolves round the earth during its revolution round the sun it traces a sinuous course which nevertheless remains concave to the sun.

36. HELICAL PATH—Since the moon must keep pace with the earth in its flight with the sun, its path round the earth is a small helix in which the moon traverses about 58,893,000 miles each month or 57,451,000 miles more than are given for its theoretical orbit and over 18,000 miles more than the earth in the same period.

37. ECCENTRICITY OF ORBIT—.0549 or about 1/8

which accounts for the points of perigee and apogee. This eccentricity and the following inclination make possible the central solar eclipses and also affect the tides.

38. INCLINATION, ORBIT TO ECLIPTIC—Mean 5°9′ of arc. If we subtract this from the inclination above we find that the plane of the moon's equator apparently cuts the plane of the ecliptic at an angle of 1°32′ of arc thus marking the nodes.

39. VELOCITY OF REVOLUTION—With respect to the theoretical earth orbit it is said to average a little more than 3/5 of a mile per second or about 2,290 miles per hour In its theoretical sun orbit the velocity is about the same as the earth. These, however are purely imaginary velocities because the moon in its actual helical path travels at 22.72 miles per second or some 81,790 miles per hour. This is over 36 times as fast as is given for the theoretical orbit.

40. MEAN MONTHLY MOTION—In the sun orbit it is similar to the earth because they revolve together, but this must not be confused with its more rapid motion round the earth in the same direction by which it seems to repeatedly overtake the sun. See 39.

41. PERIOD OF REVOLUTION, SIDEREAL—Mean 27 days, 7 hours, 43 minutes, 11.5 seconds. This is the same as the period of rotation noted above and extends from the moment the moon apparently leaves a star in the zodiac until it returns to that star again and varies with the eccentricity and perturbations. The revolution is from east to west like the planets but the rotation of the earth seems to reverse it.

42. PERIOD OF REVOLUTION, SYNODIC—Mean 29 days, 12 hours, 44 minutes, 2.8 seconds. This is determined from many eclipses and is the time during which the moon passes from the sun apparently round the ecliptic and back again to the sun. This is a lunar month or lunation and its greater length is due to the orbital motion which carries the earth 2 days and 5 hours beyond where it was on the first of the month. On account of its eastward motion of 13° per day round the earth the moon rises about 51 minutes later each day and thus appears to overtake the sun nearly 13 times a year.

43. HELIOCENTRIC LONGITUDE—Its average will be about the same as the earth and its latitude is always changing.

44. LONGITUDE OF PERIHELION—For its sun orbit this will also be similar to that of the earth and aphelion will be opposite. But more important for us are the longitudes or perigee and apogee. The former is the point of the moon's nearest approach to the earth, the latter its farthest point away. On account of their constant change we do not give them but refer the reader to some good current almanac.

45. LINE OF APSIDES—With respect to its sun orbit this imaginary line will be the earth's. With respect to its earth orbit the line of apsides which joins the points of perigee and apogee is said to rotate in about 8.85 years. This line is the major axis of the orbit and divides it into equal parts.

46. LONGITUDE OF ASCENDING NODE—Since the positions of the nodes are constantly changing we do not set down any definite longitude but refer the reader again to a good current almanac.

47. LINE OF NODES—Owing to the influence of the sun the moon's line of nodes rotates in about 18.6 years. This causes the nodes themselves to rotate in a westward or backward direction called "regression."

48. ARC OF RETROGRADE—The moon does not retrograde because the speed of its revolution round the earth is faster than that of the earth round the sun.

49. PERTURBATIONS IN ORBIT—These are small orbital variations due to the sun and nearby planets. They sometimes amount to 1°30′ and cause a variation of between two and three hours in the moon's period of revolution. Regression is one of its perturbations and it is said there are over a thousand of them.

50. ELONGATION—This is the angle of difference in longitude between the positions of the sun and moon as seen by us and is always changing.

51. CONJUNCTIONS—The moon is in conjunction with the sun when their longitudes are equal. Then the elongation is

0° and the moon is new. The moon is in conjunction with a planet when their positions in right ascension and declination are the same although the latter may differ by a small angle.

52. QUADRATURE—This occurs at what we call half moon when we actually see only one-quarter of its surface. These are called the first and last quarters and their elongation is 90° or 270°.

53. OPPOSITION—The moon is in opposition to the sun when it is full and the elongation is 180°. At conjunction and at opposition the moon is said to be in syzygy.

54. PHASES—A phase is a change in the amount of the surface of the moon from which we receive reflected sunlight and depends on the apparent distance the sun and moon are apart in the sky. At new moon the dark side is toward us and we cannot see the lighted surface, but in a short time the new moon, in the form of a thin crescent with its back to the setting sun, becomes visible. This gradually increases and soon we see "the old moon in the new moon's arms," due to reflected light from the earth. After about seven days it reaches first quarter when we see the right half of the disc, but only a quarter of the surface, then it passes through a similar period to full moon when we see its entire disc but only half its surface, from this point it decreases on its way to last quarter when we see the left half of the disc or quarter of its surface, and finally it comes to the position of new moon again. Between first quarter and opposition and between opposition and last quarter the phase is more or less gibbous. The Metonic or lunar cycle is a period of about 18.6 years after which the phases repeat in the same order, but not at the same locations on the earth. When new the moon rises and sets with the sun, at first quarter it rises at noon and sets at midnight, when full it rises at sunset and sets at sunrise, at last quarter it rises at midnight and sets at noon. The harvest moon and the hunter's moon are due to the daily retardation of 51 minutes mentioned above. Sometimes this is greater than at others according to the moon's position on the eastern horizon. In northern latitudes it is most marked during September when the moon's apparent path is nearly parallel with the horizon. If at this time the moon is full it will rise at about the same time for several nights thus producing the harvest moon and prolonging the duration of moonlight so

favorable for harvesting. In October the conditions are much the same and then it is called the hunter's moon.

55. OCCULTATIONS—These occur whenever the moon passes between us and some star or planet. They are very frequent but only the more important are noted. See Observer's Handbook.

56. TRANSITS—The only solar transits made by the moon occur when it eclipses the sun. No other celestial body can transit the moon because it is nearest to us.

57. SATELLITES—There are probably no moons attending the satellites.

58. ECLIPSES—Lunar eclipses occur whenever the full moon, in its revolution round the earth, passes into the earth's shadow. This can happen only when the earth is at or near one of the moon's nodes. A partial lunar eclipse occurs when the sun is so far from the moon's node as to allow the moon to only partially hide in the earth's shadow. A total eclipse occurs when the sun is so near the moon's node that the moon is wholly hidden in the earth's shadow which stretches out into space from 845,000 to 873,000 miles according to its orbital position with reference to the sun. The diameter of the earth's shadow where the moon cuts it is about three times that of the moon, so that a total lunar eclipse may last about 2 hours. There is an interesting relation between solar and lunar eclipses because the moon has to do with both. About two weeks before and after a total eclipse of the sun there will usually be a partial eclipse of the moon, and about two weeks before and after a total eclipse of the moon there will always be a partial eclipse of the sun. There must be at least two solar eclipses each year and there may be five. Ordinarily there are also two lunar eclipses and there may be a third but sometimes none occur, according to the relation of the earth's shadow to the moon's node. Seven occurred in 1805 and the same number will occur again in 1935.

59. SPECIAL FEATURES—Under "Markings" we noted some of these but now we shall treat them in more detail:

a. Sea Basins—As no water is present on the moon these large shaded areas must now be only arid valleys. They vary in size, the largest being about the area of our Mediterranean Sea. With a little study one can soon pick out Serenitatis, Imbrium, Crisium and others.

b. Mountain Ranges—There are ten or more of these which vary in height from 1,000 to 20,000 feet, one or two of them being nearly as high as our Himalayas. They are all very slim and steep, compared with ours because the agencies of erosion are lacking. One soon learns to know the Apennines, the Alps and the Caucasus ranges. Several bear the names of great men like Doerfel, Huygens and Leibnitz.

c. Lunar Craters—Whether volcanic or meteoric or both, the typical crater is almost circular like a gigantic wheel. The rim is a small round mountain range and the hub is a central rugged mass. The inner plane is often as deep below the surrounding region as the rim is high above it and the diameter varies from 5 to 50 times the depth. There are some 30,000 of these, many having diameters 10 times as great as any on earth, and they make the moon look like a victim of big-pox. We soon become acquainted with Ptolemy 115 miles across, Copernicus 56 miles, and Tycho 53 miles in diameter.

d. Rills and Rays—There are more than 1,000 rills or cracks still yawning open. Some are very crooked, others very straight, no matter what obstruction they encounter. They vary in width from a few rods to two miles and in depth from a few yards to unknown distances and extend as much as 150 miles. There are also a number of large craters like Tycho from which radiate many rays that seem to have been eruptive cracks, now apparently filled with some bright material from below.

e. Influences—A great variety of conditions on the earth have been blamed on the moon; some scientifically, others superstitiously. There is, of course, no question about the tidal effect of the moon's attraction and we have long since learned that the so-called spring tides are the highest and occur twice a month in any month when the sun and moon in line exert their combined gravitational pull upon the seas and oceans. The neap tides are the lowest because they occur when the sun and moon apply their forces in opposite directions with respect to the earth. But long before the effect of the moon's mass was known, and even in our own time, there have been some curious notions about the moon's influence. Its phases and eclipses and even its presence in the sky were supposed to affect the weather, the germination of seed, the seasoning of timber, the curing of pork, the laying of eggs, the setting of hens and even the human nervous system to the point of producing insanity if one should fall asleep in the moonlight. This is all absurd for the moon shows the same phases to all the world every 24 hours, but we know that the weather, et cetera, are by no means the same everywhere. The sun is rather the source of the energy that affects our atmosphere and most of these things.

60. HABITABILITY—Without air or water we shall look in vain for any form of life on the moon. It may be that with the aid of the 200-inch reflector now under construction we shall be able to guess a little better.

NOTE:—The hundred and one puzzles you have mastered are mere child's play compared with the inspiring and baffling task of building an approximate model of the sun-earth-moon combination. Don't fail to try it.

CHAPTER VIII.

MARS.

1. NAME—Among the Greeks his name was Ares, son of Zeus and Hera and consort of the goddess Aphrodite. According to Homer he was father of Phobos and Deimos, whose names have been given to his two satellites. Among the Romans he was called Mars, son of Jupiter and Juno and husband of the goddess Bellona.

2. MYTH—In Roman mythology Mars was the god of war, pestilence and bloodshed and his sacred emblems, the spear and shield, were said to have fallen from heaven. Roman legend claimed him as the father of Romulus and Remus, the traditional founders of Rome, while Greek legend tells of his connection with the founding of the council of the Areopagus near Athens.

3. SYMBOL—♂ A circle surmounted by an oblique dart representing the shield and spear, which were the main weapons of ancient warfare.

4. SOUND—In the Music of the Spheres Mars was supposed to have the tenor part.

5. COLOUR—The ruddy appearance of Mars is probably due to the large areas of reddish brown soil, sand and rock which cover about 3/5 of the surface. There are also a number of smaller dark areas which may be vegetation of some kind.

6. MARKINGS—There are snow caps at the poles,, three zones between and many lines which radiate from dark spots, one of which is called Syrtis Major, the great sand bank, and another Solis Lacus, the lone lake or "Eye" of Mars. Clouds and frost are sometimes visible, the former at the fringe of the polar caps and the latter on the eastward edge at sunrise. The so-called seas are evidently not open water but only wide-spread marshes.

7. STELLAR MAGNITUDE—From −2.1 to 3.1. This variation is due to our orbital position with respect to Mars.

At conjunction its brightness is similar to that of Polaris, and at ordinary opposition it becomes 23 times as bright.

8. GREATEST BRILLIANCY—This occurs at most favorable opposition late in August every 15 years when the earth catches up to Mars during his perihelion passage. At this time the planet shines with about 60 times its light at conjunction.

9. ANGULAR DIAMETER—Mean 14″ of arc. At our nearest approach to Mars it is almost 25″ and at its greatest distance from us it is only about 4″ of arc. Its angular diameter at mean distance from the earth by which its linear dimensions are obtained is about 6″ of arc.

10. LINEAR DIMENSIONS—Its equatorial diameter is close to 4,215 miles or a little more than half that of the earth. The polar diameter is a little less and its circumference is about 13,240 miles.

11. AREA OF SURFACE—About 55,800,000 square miles or .28 of the earth and 1/42,000 of the sun.

12. VOLUME—About 39,210,000,000 cubic miles or a little more than 1/7 of the earth and about 1/8,300,000 of the sun.

13. MASS—Its weight is something like 665,000,000,000,-000,000,000 tons. This is about 1/9 of the earth and 1/3,000,000 of the sun. It is measured by the attraction of Mars for its moons.

14. DENSITY—About 3.92 times that of water or .7 of the earth's amount and a little over 3 times that of the sun.

15. SURFACE GRAVITY—About .38 of the earth. The inhabitants should be tall and their work rather easy.

16. FALLING BODIES—These attain a speed of slightly more than 6 feet per second during the first second.

17. VELOCITY OF ESCAPE—3.22 miles per second, which means that it is not half as difficult to jump off from Mars as it is to escape from the earth.

18. PERIOD OF ROTATION—24 hrs. 37 min. 22.6 sec.

This is measured by the motion of the markings on its surface and makes a day similar to ours.

19. VELOCITY OF ROTATION—About 628 miles per hour. This is less than 2/3 as fast as the earth.

20. DAYS IN ITS YEAR—There are about 670 Martian days in its year, which is almost twice as long as ours.

21. MAGNETISM—Here we have a small world only 1/7 the size of the earth with only 1/9 of its mass and rotating only 2/3 as fast so that its magnetic energy may be rather weak.

22. OBLATENESS—.0052 or 1/192. Since the surface gravity is only a little more than 1/3 of ours and the density only 7/10 of the earth's one might expect to find greater polar depression and equatorial bulge but its slow rotation probably accounts for its absence.

23. DIRECTION OF AXIS—This is at R.A. 22 hrs. 10 min. and Decl. +54° in Cygnus near Deneb, which is thus the pole star of Mars. The south pole points toward the southern constellation, Argo.

24. INCLINATION, EQUATOR TO ORBIT—23°40′ of arc. This is similar to that of the earth and causes seasons similar to ours but on account of its greater orbit they are nearly twice as long. Its seasons are naturally colder than ours. On the northern hemisphere late spring, summer and early fall cover 381 days, while late fall, winter and early spring cover 306 days. On the southern hemisphere the climatic conditions are just the reverse and their difference more pronounced.

25. LIBRATION IN LATITUDE—The very slight angle of inclination between the plane of the orbit and that of the ecliptic makes any north and south movements quite inconspicuous.

26. LIBRATION IN LONGITUDE—Since the eccentricity of the orbit is great there are east and west oscillations of the planet but they are unimportant because it rotates on its axis every day and thus enjoys sunlight and shadow over its entire surface.

27. SOLAR RADIATION—Mean .43 of the earth's amount or less than half as much per unit area. It receives half as much again at perihelion as at aphelion and passes its perihelion during its southern summertime.

28. ALBEDO—Mean .15. The surface of Mars must be rough and clouds are few as well as the fact that the south polar cap is greatly reduced at the time of opposition.

29. TEMPERATURE—The most recent measures with the thermocouple using the F. scale give 15° to 50° for the south pole summertime, 65° to 75° for the south temperate zone in summer, and 65° to 85° at noon in the tropics. In the north temperate zone during the winter it varies from 30° to 60° below zero while nearer the north pole it is between 10° and 40° below zero.

30. ATMOSPHERE—This is probably only half as dense as ours, and is said to be 120 miles high. The planet's disc, unlike that of Venus, occults stars quite sharply because the percentage of water vapor is unusually low and clouds are rare.

31. PARALLAX—The horizontal parallax on January 15, 1933 was 9″.84 and on July 15, 5″.72 of arc. This variation is due to the relative positions of the earth and Mars in their orbits. The mean parallax from which the distance is computed is about 5″.77 of arc.

32. DISTANCE FROM EARTH—This varies from about 35,000,000 miles at nearest special opposition to about 250,000,000 miles at farthest conjunction and its mean distance from us is about the same as the sun.

33. DISTANCE FROM SUN—Mean about 141,540,000 miles. At perihelion it is close to 128,320,000 miles and at aphelion it is 154,760,000 miles. This is the cause of the variation in the amount of solar energy received and is due to the great eccentricity of the orbit.

34. SOLAR ASPECT—The mean angular diameter of the sun as seen from Mars is about 21′ or 2/3 of what it appears to us.

35. DIMENSIONS OF ORBIT—The mean diameter of its theoretical orbit is about 283,000,000 miles from which we

get a circumference of about 890,000,000 miles. But as we have already seen the real path is a quite open helix.

36. HELICAL PATH—In this continuous helical journey along with the sun Mars traverses, during each revolution of 687 days or one Martian year, some 1,162,200,000 miles or about 272,200,000 miles more than are given for its theoretical orbit and 414,712,000 miles more than the sun during the same period. As we have previously noted, these greater distances require higher speed. See Fig. IV. and item 39.

37. ECCENTRICITY OF ORBIT—.093. The sun is thus out of centre about 13,000,000 miles, which amounts to a total difference of 26,000,000 miles between perihelion and aphelion distances. This accounts for the unequal seasons on the two hemispheres, those of the southern hemisphere being the more extreme because Mars passes its perihelion during the southern summertime.

38. INCLINATION, ORBIT TO ECLIPTIC—1°51′ of arc. This is very small and provides no appreciable north and south librations. The points of apparent intersection of the orbit and ecliptic are its nodes.

39. VELOCITY OF REVOLUTION—This varies rather widely on account of the eccentricity. Its mean for the theoretical orbit is about 15 miles per second but in its helical path it is about 19.54 miles per second.

40. MEAN MONTHLY MOTION—In the theoretical orbit it is said to be about 15°36′ of arc or about 38,566,600 miles but in its real helical path it actually covers over 50,362,000 miles.

41. PERIOD OF REVOLUTION, SIDEREAL—687 o our days, usually called mean solar days, or about 1 year and 11 months. This is the time it takes Mars to make a circuit of the sky with reference to any particular star in the zodiac. See Mer. 41.

42. PERIOD OF REVOLUTION, SYNODIC—Mean 780 of our days or 2 years 1 month and 18 days. This is the length of time it takes the earth to make an apparent circuit of the sky or a revolution and catch up to Mars again. You will

notice that in their synodic periods Mercury and Venus have to catch up with the earth, but the earth has to catch up with Mars and the outer planets.

43. HELIOCENTRIC LONGITUDE—On January 1, 1933 Greenwich civil time it was 134°35′54″ of arc. The heliocentric latitude is not given because it is always changing. See Mercury 43.

44. LONGITUDE OF PERIHELION—About 334°49′32″ of arc. This is also heliocentric and the aphelion point is opposite. The latitude of each is governed by the inclination of the orbit to the ecliptic. See Mercury 44.

45. LINE OF APSIDES—This imaginary line joins the above points, is the major axis of the orbit and divides it into equal parts.

46. LONGITUDE OF ASCENDING NODE—49°2′27″ of arc and the descending node is opposite. These apparent intersections have no latitude because they are on the ecliptic. See Mercury 46.

47. LINE OF NODES—The nodes are joined by this imaginary line which thus divides the orbit with respect to the ecliptic but not into equal parts because of the eccentricity.

48. ARC OF RETROGRADE—18° of arc. This motion is only apparent and is due to the combination of the orbital motions of the earth and Mars and takes about 70 days. It occurs only at the time of opposition which is always on the meridian at midnight. For a short time at the beginning and at the end of this movement the planet is said to be "stationary."

49. PERTURBATIONS IN ORBIT—These are not very important because Mars is so far from the earth on the one side and also so far from Jupiter on the other. Mars itself will easily overmatch any attraction of the planetoids.

50. ELONGATION—For Mars and the outer planets this may be anywhere from 0° to 180°. At 0° it is in conjunction, at 90° and 270° it is in quadrature and at 180° it is in opposition.

51. CONJUNCTIONS—Conjunctions of Mars and the

outer planets with the sun are similar to superior conjunctions of Venus and Mercury with the sun. The average distance of Mars at this time is about 234,500,000 miles. Conjunctions occur in harmony with the synodic period every 780 days. They also happen with the moon and the other planets.

52. QUADRATURE—This is an east or west position of Mars and the outer planets when the body is on a line from the earth to the planet at right angles to a line from the earth to the sun. It occurs twice a year.

53. OPPOSITION—This occurs with Mars and the outer planets when they reach a point in their orbits directly opposite the sun from us. As we have already remarked we sometimes come within 35,000,000 miles of Mars at this time. After such a close approach the distance between us at subsequent oppositions gradually increases for about 7 and 1/2 years when it occurs in February and the distance is slightly more than 61,000,000 miles; from this time the distance decreases for another 7 and 1/2 years only to begin again in August.

54. PHASES—The planets beyond our orbit do not exhibit a crescent phase but are always gibbous or full. Their phases occur between quadrature and opposition and between opposition and quadrature and are most gibbous at the latter.

55. OCCULTATIONS—Mars repeatedly occults its own satellites as well as many stars in the zodiac and sometimes the moon occults Mars.

56 TRANSITS—Planets outside our orbit cannot transit the sun for us but may easily do so for observers on planets outside them. The only transits are of Mars itself by its satellites which occur whenever they pass directly between us and their primary. Occasionally the satellites will transit the sun as indicated in item 58.

57. SATELLITES—Mars has two—Phobos and Deimos, which revolve round its equator. Both were discovered by Hall at Washington in 1877. He named them after two of Mars' attendants, either horses or sons, the one Fright and the other Terror. The former is nearer and brighter than the latter and is said to be from 6 to 10 miles in diameter and 3,700 miles from the surface of Mars. It revolves in the very brief period of 7

hours 39 minutes, thus circling its primary more than 3 times in a Martian day and therefore rising in the west and setting in the east. The latter is from 5 to 8 miles in diameter, is 12,600 miles away, revolves in 30 hours 18 minutes and thus remains above the horizon of Mars for about 60 hours at a time and presents all its phases twice between rising and setting. These moons are so small that the light of either on Mars is no more than we receive from Venus and even when both appear together in the sky they are of no real value to the Martians.

58. ECLIPSES—These like the transits are insignificant for us but to the Martians they may be very interesting. When Phobos passes directly between Mars and the sun they would enjoy a partial or an annular eclipse. The projection of Phobos on the sun would be a large dark spot and the shadow of Phobos on Mars would be very small. Deimos would be just as interesting but its shadow cannot reach Mars.

59. SPECIAL FEATURES—Mars is noted for its clear surface, its unique markings, its two moons, one of which revolves three times as fast as the planet itself, its ruddy colour, its large eccentricity and its climatic conditions which may make it an abode of life.

60. HABITABILITY—From all that has been said above it would seem quite reasonable to believe that Mars is habitable.

NOTE—For the best times and conditions of observation, see the Observer's Handbook or some good current almanac.

CHAPTER IX.

PLANETOIDS.

This is a very brief chapter, in which we shall not follow the order of items closely but only as our summary requires.

The name, as given above, is the only proper one because these little bodies are not astral in any sense except that they look like stars. They should not be called asteroids because their brightness is only reflected sunlight. More than a thousand of them have now been discovered, charted and numbered and there are probably many hundreds more of smaller size revolving between the outer planets. We shall speak in detail of only five; the first four discovered, which are also the largest, and one of the more recent which is among the smallest known. The visual method of search has long since given place to the camera.

Astronomers have used mythological names for many of them and have also numbered them with the date of discovery. No. 1 was discovered by Piazzi on January 1, 1801, and is called Ceres after the goddess of grain and guardian of agriculture. No. 2 was discovered by Olbers in 1802 and is called Pallas, the goddess of wisdom and guardian of learning. No. 3 was discovered by Harding in 1804 and is called Juno, the goddess of heaven and guardian of the family. No. 4 was discovered by Olbers in 1807 and is called Vesta, the goddess of the hearth and guardian of the home. No. 433 was discovered by Witt in 1898 and is called Eros, the god of love and guardian of productivity. By 1900 there were 463 recorded; in 1920 the list had grown to 944 and in 1923 it reached the 1,000 mark. Since then a few more have been added.

The stellar magnitude of these little worlds is very low. The brightest, not the largest, is Vesta, which is of the sixth magnitude and may be occasionally seen with the naked eye. All the others require a telescope to find them and then one must know them well to be sure of their identity. Eros was of the eleventh magnitude when discovered but this varies with its distance and the surface it presents to us.

The angular diameters of some are known but most of them are very difficult or impossible to measure because of their smallness, distance and irregularity of shape. The linear dimensions of the five mentioned above are: Ceres, 480 miles in diameter and 1,500 miles in circumference; Pallas, 304 miles in diameter and 955 miles in circumference; Juno, 120 miles in diameter and 377 miles in circumference; Vesta, 240 miles in diameter and 764 miles in circumference; while little Eros is very irregular and is said to average between 8 and 10 miles in width and from 25 to 30 miles in length.

The areas of their respective surfaces are: Ceres, 739,000 square miles; Pallas, 290,000 square miles; Juno, 45,000 square miles; Vesta, 181,000 square miles; and Eros, possibly 1,000 square miles.

Their volumes are: Ceres, 57,900,000 cubic miles; Pallas, 14,710,000 cubic miles; Juno, 905,000 cubic miles; Vesta, 7,240,000 cubic miles; and Eros only about 4,000 cubic miles. The combined volume of all the planetoids would not make a sphere 1,000 miles in diameter. The masses all combined would probably not amount to 1/1,000 of the earth.

Their densities are very difficult to determine but it is said that if the density of Ceres were similar to that of the earth its mass might be 1/8,000 and its surface gravity about 1/30 of the earth's. The speed of falling bodies would be about 8 inches per second at the end of the first second.

Their albedos are: Ceres, .06; Pallas, .07; Juno, .12; Vesta, .26; while Eros has a peculiar variation with a period of something like 5 hours 16 minutes and 13 seconds due to its rough contour.

Under the powerful perturbing influence of Jupiter, many of these bodies have been forced into orbits which lie in the great open space between its orbit and that of Mars. The mean distances of these five are: Ceres, 255,000,000 miles; Pallas, 250,000,000 miles; Juno, 248,000,000 miles; Vesta, 220,000,000 miles; and Eros, 135,430,000 miles.

The angles of inclination vary from almost 0° to about 50° but most of them do not reach 1/3 of the maximum, the average being about 9°30′. Some of them reach beyond the zodiac while the plane of the orbit of Eros is at an angle of 11° from the ecliptic.

The ratios of eccentricity of the orbits vary from almost .0 to about .65 but most of them do not reach half of the maximum, the average being about .15. A few of them swing out beyond the orbit of Jupiter, while others come within that of Mars. In the case of Eros, an eccentricity of .22 enables it to come before, at and after its perihelion passage which is only 21° from ours, far within the orbit of Mars and as close to us as 13,850,000 miles. At perihelion it is about 105,200,000 miles from the sun but at aphelion it sweeps out to 24,000,000 miles beyond the orbit of Mars and reaches a point 165,630,000 miles from the sun.

The sidereal periods range from less than 2 to more than 13 years. Ceres takes 1,681 days, Pallas 1,685 days, Juno 1,592 days, Vesta 1,326 days, and Eros only 643 days. Its synodic period is 845 days and it retrogrades 30′ of arc.

The planetoids have arranged themselves in singles, doubles and groups and the study of the groups in connection with Bode's law is very interesting. They are probably not the debris of an exploded planet but simply unused material floating in space.

An item of interest has just been received regarding a new planetoid designated 1932 H.A. It is between 2 and 3 miles in diameter; at perihelion it is 63,000,000 from the sun; its period is a little over 21 months; its orbit is inclined from the ecliptic 6°30′ and has a circumference of about 280,000,000 miles. In 1932 it came within 7,000,000 miles of the earth and it can come within 2,500,000 miles of us, or nearer than any other heavenly body except the moon or an occasional comet or meteor.

CHAPTER X.

JUPITER.

1. NAME—The Egyptians gave this planet the name of their greatest god Hor, who was the hawk-headed, double crowned god of the sun. The Chinese named it the Regulator because of its regularity of motion. The Greek name was Zeus, the father of all the gods and ruler of Mount Olympus. The Romans called it Jove or Jupiter, the wielder of the thunderbolts.

2. MYTH—According to the Greeks, Zeus was one of the sons of Chronos and Ops, while the Romans said he was the son of Saturn and Rhea. As Saturn had driven Ophion from Olympus so Jupiter in turn drove Saturn from his high position and became the father and ruler of a younger generation of divinities. The imperious Juno, attended by the rainbow and the peacock, was his queen.

3. SYMBOL—♃ This is supposed to represent a flash of lightning or the first letter of Zeus.

4. SOUND—In the Music of the Spheres the role of Jupiter was bass.

5. COLOUR—To unaided vision Jupiter shines with a yellowish white glow but in a good telescope, under favorable seeing conditions, there appear a variety of tints such as pink, amber and light brown similar to our cloud colours.

6. MARKINGS—There is a broad, light-coloured equatorial belt about 10,000 miles wide, while above and below it are two darker belts of almost equal width. These are followed, toward the poles, by other narrower belts that present a rippled appearance. This banded effect pertains only to the cloud envelope which is so dense and deep that the actual surface of Jupiter, like that of Venus, is never seen. On account of the rapidity of rotation these markings are always changing and in 1878 a great oval pink area 30,000 miles long and 7,000 miles wide appeared.

7. STELLAR MAGNITUDE—From −1.5 to −2.5. Jupiter is the second brightest planet and 5 times as brilliant as Sirius. This is mainly due to its great size and the cloud envelope that surrounds it continually.

8. GREATEST BRILLIANCY—This occurs when opposition and perihelion are coincident.

9. ANGULAR DIAMETER—Mean about 37″ of arc. Recently, on account of its oblateness, it has been set at 35″.44 for the polar and 37″.72 for the equatorial diameter. Its angular diameter at mean distance from us is also 37″ of arc.

10. LINEAR DIMENSIONS—Its mean diameter is about 86,700 miles, its polar 83,000 miles and its equatorial 88,600 miles. This is more than 10 times the earth's diameter and slightly more than 1/10 of the sun's. The circumference is about 272,000 miles.

11. AREA OF SURFACE—About 23,620,000,000 square miles or 120 times the earth and about 1/100 of the sun. We must remember that it is probably semi-gaseous.

12. VOLUME—About 341,000,000,000,000 cubic miles or slightly more than 1,300 times the size of the earth or about 1/1,000 of the sun. It is the largest of all the planets.

13. MASS—318 times the earth or 1/1,000 of the sun and nearly 3 times that of all the other planets put together. Its weight would be nearly 2 septillion tons. This huge mass causes the sun-Jupiter system to revolve round their mutual centre of gravity about 7,000 miles outside the sun and thus complicates the orbit problem.

14. DENSITY—About 1.34 times that of water or nearly the same as the sun and .242 of the earth.

15. SURFACE GRAVITY—2.65 times that of the earth. The fast rotation and great oblateness make the gravity at the poles 15 per cent. less than at the equator.

16. FALLING BODIES—These attain a speed of about 41 feet per second during the first second.

17. VELOCITY OF ESCAPE—38.04 miles per second or about 5.5 times that of the earth but only 1/10 that of the sun.

18. PERIOD OF ROTATION—Mean 9 hrs. 55 min. The equatorial belt rotates in about 5 min. less so that during 85 rotations the equator makes about 86. This is a brief day of only about 5 hrs. light and 5 hrs. darkness.

19. VELOCITY OF ROTATION—7.73 miles per second or 27,800 miles per hour and about 26 times as fast as the earth. This high speed causes the oblateness, the differences in gravity and also the violent equatorial winds which are said to rage at about 250 miles per hour.

20. DAYS IN ITS YEAR—There are about 10,484 days in a Jovian year.

21. MAGNETISM—If high velocity of rotation helps to produce magnetic currents we should expect to find some powerful energies there.

22. OBLATENESS—.056 or about 1/18. Jupiter is the most oblate of all the planets except Saturn and its shape is quite noticeable in a telescope.

23. DIRECTION OF AXIS—On account of the very small inclinations this will not be far from the pole of the ecliptic itself. See Fig. VII.

24. INCLINATION, EQUATOR TO ORBIT—3°5′ of arc. This angle is so small that the Jovian days will each be almost the same length throughout the long year and produce almost perpetual seasons with hardly any climatic changes.

25. LIBRATION IN LATITUDE—The very small inclination of the orbit to the ecliptic makes any possible north and south movements quite unimportant.

26. LIBRATION IN LONGITUDE—The very small eccentricity of the orbit makes any east and west oscillations almost imperceptible.

27. SOLAR RADIATION—.037 of the amount we receive,

that is, we get about 27 times as much per unit area. It sends us about 1/1,000 of the amount we receive from the moon.

28. ALBEDO—Mean .5 with a variation of about .1 according to its position in the orbit and the phase it presents to us.

29. TEMPERATURE—Since Jupiter receives only 1/27 as much light as we do, its cloud surface will be very cold, perhaps −266° F. It seems possible, however, that the temperature of the actual surface may not be so cold and that internal sources may provide much local heat which is largely retained by the unbroken cloud envelope.

30. ATMOSPHERE—In the spectrum of Jupiter's clouds there are dark bands which indicate a very dense atmosphere. It has been suggested that these clouds may be composed of some substance which cannot freeze such as carbon dioxide but this may not be necessary.

31. PARALLAX—The horizontal parallax on January 15, 1933 was 1″.82 and on July 15, 1″.48 of arc. This shows very little variation during 6 months because Jupiter is so far away and moves so slowly. The mean parallax by which the distance is computed is about 1″.69 of arc.

32. DISTANCE FROM EARTH—Mean 483,600,000 miles. At nearest opposition it is about 367,000,000 miles and at farthest conjunction it is more than 599,700,000 miles.

33. DISTANCE FROM SUN—Mean about 483,300,000 miles. At perihelion it is about 460,000,000 miles and at aphelion over 506,700,000 miles. Jupiter is more than 5 times as far from the sun as we are and it would take almost 5,600 of these great spheres to bridge the gulf between their centres.

34. SOLAR ASPECT—As seen from Jupiter the sun's mean angular diameter would be only 6′10″ of arc or about 1/5 the breadth it shows to us and 1/27 the area.

35. DIMENSIONS OF ORBIT—The mean diameter of the theoretical orbit is given as 967,200,000 miles and its circumference 3,039,000,000 miles but its real path is a very open helix.

36. HELICAL PATH—In this continuous helical journey along with the sun Jupiter traverses, during each revolution of about 12 of our years or one Jovian year, some 5,608,860,000 miles or about 2,571,860,000 miles more than are given for its theoretical orbit and 893,360,000 miles more than the sun during the same period. This requires a higher speed. See Item 39 and Fig. IV.

37. ECCENTRICITY OF ORBIT—.048. Thus the sun is out of centre some 23,500,000 miles or a difference of about 47,000,000 miles between perihelion and aphelion distances. This is so small compared to the orbit that there is no appreciable difference in the intensity of the sun's radiation and it causes but slight variation in the planet's orbital velocity.

38. INCLINATION, ORBIT TO ECLIPTIC—1°18′14″ of arc. This is such a small departure from the ecliptic that the ancients noticed it and called it the ecliptic planet. The points of apparent intersection are its nodes.

39. VELOCITY OF REVOLUTION—In the theoretical orbit assigned to it a speed of 8 miles per second or 29,000 miles per hour has been suggested but this is wholly imaginary because it is flying in an endless helical path at almost 15 miles per second instead.

40. MEAN MONTHLY MOTION—In the theoretical orbit it is said to be about 2°30′ of arc or about 21,090,300 miles but in its real helical path it actually covers over 38,950,400 miles.

41. PERIOD OF REVOLUTION, SIDEREAL—11.86 of our years. or 4,332 mean solar days. See Mercury 41.

42. PERIOD OF REVOLUTION, SYNODIC—Mean 399 of our days. This is the average interval between conjunctions or oppositions. See Mercury 42.

43. HELIOCENTRIC LONGITUDE—On January 1, 1933 Greenwich civil time it was 163°10′50″ of arc. The latitude is not given because it is always changing and with Jupiter it is very small.

44. LONGITUDE OF PERIHELION—About 13°14′35″

of arc. Aphelion is opposite and both are heliocentric positions. Their latitudes are governed by the inclination of the orbit to the ecliptic.

45. LINE OF APSIDES—This line joins the above points, is the major axis, divides the orbit into equal parts and rotates at about 57″ of arc per year.

46. LONGITUDE OF ASCENDING NODE—99°46′17″ of arc. The descending node is opposite. These apparent intersections have no latitude because they are on the ecliptic. See Mercury 46.

47. LINE OF NODES—This is called the nodal line which connects them and divides the orbit with respect to the ecliptic but not in equal parts because of the eccentricity.

48. ARC OF RETROGRADE—9° of arc. This occurs almost annually. There are 121 days of retrograde and 279 days of direct motion each earth year. The "stationary" points are reached at the beginning and the end of this arc.

49. PERTURBATIONS IN ORBIT—The great mass of this planet makes it difficult for lesser bodies to affect it by their attraction. Saturn will naturally make himself felt whenever Jupiter draws near and even Uranus is known to exert its influence over a period of about 900 years called the "long inequality." In all cases the attractions are mutual but not equal.

50. ELONGATION—This is the angular distance between the sun and the planet as seen by us and varies from 0° to 180° according to the planet's position in its orbit.

51. CONJUNCTIONS—These occur with the sun every 399 of our days but about 5 weeks later each time. They also occur with the moon and the other planets.

52. QUADRATURE—There are two each year, one east and the other west of the sun. There are 175 days between them and at each point the planet is 90° of arc from the sun as seen by us.

53. OPPOSITION—These occur on the opposite side of the orbit from the conjunctions every 399 days and, like them, 5 weeks later each time. At this time the retrograde motion occurs

54. PHASES—These are very slight and are always gibbous at or near quadrature on the limb farthest from the sun. Otherwise they are full.

55. OCCULTATIONS—These are occurring repeatedly because the larger satellites revolve in almost the same plane as the planet's equator and thus frequently pass behind it. Stars also are occulted.

56. TRANSITS—These occur for the same reason as the occultations but they are visible on the face of the planet in the form of white spots with dark spots as shadows.

57. SATELLITES—These are nine in number. The first four are the largest, were discovered in 1610 by Galileo and have been called the Galilean satellites. No. 1, Io, is of magnitude 6.5, diameter 2,450 miles, distance from Jupiter 261,000 miles, and revolves in 1 dy. 18 hrs. 28 min. No. 2, Europa, is of magnitude 6.5, diameter 2,050 miles, distance 415,000 miles, and revolves in 3 dys. 13 hrs. 14 min. No. 3, Ganymede, is of magnitude 6, diameter 3,560 miles, distance 664,000 miles, and revolves in 7 dys. 4 hrs. No. 4, Callisto, is of magnitude 7, diameter 3,350 miles, distance 1,167,000 miles, and revolves in 16 dys. 16 hrs. 32 min. The other five have numbers but no names. No. 5 is the nearest of all, is of magnitude 13, diameter 100 miles, distance 112,500 miles, and revolves in 11 hrs. 57 min. The remaining satellites are very small and very distant and for their details we refer the reader to the Observer's Handbook. All the moons that shine on the night side of Jupiter at any one time do not furnish 1/16 of the amount we receive from our full moon. Nos. 8 and 9 revolve backward. The four large satellites vary in brightness according to their periods of revolution and probably present the same face to their primary.

58. ECLIPSES—These, like the transits, are occurring continually. Each year about 9,000 take place. Nos. 1, 2, 3 are eclipsed during each revolution because they are in almost the same plane as Jupiter's equator, but No. 4 escapes sometimes on account of its greater inclination. It was the differences in the times of these eclipses that attracted Roemer's attention and by which he was able to measure the distance of the sun and the speed of light.

59. SPECIAL FEATURES—Jupiter is the largest of the planets and is almost a mean between the sun and the earth. It is probable that it still has much internal heat. With its nine satellites it must have been a miniature solar system. Its small inclinations make its seasons almost equal and unchanging. It possesses a strange element in its atmosphere which is different from all others. It has captured a family of over 30 comets and keeps them revolving round itself and the sun.

60. HABITABILITY—From the great variety of unusual conditions noted above, it is quite evident that no life as we know it can exist on Jupiter.

NOTE—For the configurations of the satellites and the best times and conditions for observation, consult the Observer's Handbook or some good current almanac.

CHAPTER XI.

SATURN.

1. NAME—Saturn was the name of an ancient mythical Roman king who had been lord of Mount Olympus but had been forced to abdicate by his powerful son, Jupiter. He is said to have ruled Italy during its golden age. His name means sower and he presided over the sowing of seed and the measuring of time. His annual festival was held on December 17, shortly after the winter sowing and became a very widely observed feast, called the Saturnalia.

2. MYTH—Saturn and Rhea, his wife, were two of the Titans who combined to drive the great serpent Ophion and his wife, Eurynome, from Mount Olympus and rule in their stead. He is said to have swallowed his children to make sure they would not rise against him but his wife saved one who, as we have seen, became the mighty Jupiter and in turn drove him from the throne.

3. SYMBOL—♄ A sickle corresponding to the scythe of Father Time and this because the planet was the slowest known to the ancients.

4. SOUND—In the Music of the Spheres the role of deep bass was assigned to Saturn.

5. COLOUR—Saturn is a rich yellow, increasing or decreasing in intensity according to its distance from us and the aspect of its rings.

6. MARKINGS—The globe is banded above and below the equator and is surrounded by three concentric rings which differ in density and amount of surface presented to us during its revolution.

7. STELLAR MAGNITUDE—At mean distance it is of the first magnitude which, like the colour, varies with its distance from us and the appearance of the rings.

8. GREATEST BRILLIANCY—This occurs when the rings present to us their largest possible area in periods of about 15 years. They are closing now but will be wide open again in 1943.

9. ANGULAR DIAMETER—Mean 17″ of arc. At opposition it is 20″ and at conjunction 14″ of arc. These and most of the following measures do not include the rings which are described under item 57. Its angular diameter at mean distance from the earth is about 16″.77 of arc.

10. LINEAR DIMENSIONS—The mean diameter is about 72,200 miles, the polar about 68,000 miles and the equatorial 76,400 miles. The mean is more than 9 times that of the earth and the circumference is about 226,900 miles.

11. AREA OF SURFACE—About 16,373,500,000 square miles or over 83 times the earth and 1/144 of the sun.

12. VOLUME—About 197,592,700,000,000 cubic miles or 760 times the size of the earth and about 1/1700 of the sun.

13. MASS—This is about 95 times that of the earth and 1/3500 of the sun. In weight it would be about 570 sextillion tons.

14. DENSITY—.72 of water or .13 of the earth and 1.39 times the sun. It is the least dense of all and this indicates a very gaseous condition.

15. SURFACE GRAVITY—About 1.18 times that of the earth but it varies by almost 1/3 between the equator and the poles.

16. FALLING BODIES—During the first second they attain a speed of about 17.52 feet per second. This is their average and is about 2 and 1/2 times what we experience on earth.

17. VELOCITY OF ESCAPE—23.53 miles per second or about 3.5 times that of the earth.

18. PERIOD OF ROTATION—10 hrs. 14 min. 23 sec. This was first determined by Hall in 1876 through his observa-

tion of the movement of a bright spot on the planet's surface. There are therefore only about 5 hours daylight and 5 hours darkness during each of its days, similar to Jupiter.

19. VELOCITY OF ROTATION—At the equator it is 6.3 miles per second or about 23,000 miles per hour and like all gaseous bodies its velocity decreases toward the poles. Its rotation is more than 22 times as fast as that of the earth.

20. DAYS IN ITS YEAR—On account of the very rapid rotation and its large orbit there are over 25,270 days in a Saturnian year.

21. MAGNETISM—With this swift rotation we are assured of much magnetic energy, especially since Saturn is still gaseous and great chemical changes are constantly going on.

22. OBLATENESS—.11. This is the greatest of all the planets and is caused by the rapidity of rotation which in turn develops the equatorial bulge, thus making the equatorial diameter 8,400 miles more than the polar.

23. DIRECTION OF AXIS—The writer has not learned the exact direction of the poles although from its inclinations it is probably somewhere in the circumpolar constellations. See Fig. VII.

24. INCLINATION, EQUATOR TO ORBIT—26°30′ of arc. This is only a little more than the earth so that each pole and each side of the rings enjoy 14 years and 8 months of sunlight and then a similar period of shadow. See Fig. VII. This produces marked seasonal changes similar to the earth but more pronounced and about 7 times as long. But since a gaseous condition still obtains we cannot think of seasons in a terrestrial sense.

25. LIBRATION IN LATITUDE—As in the case of Jupiter, the small angle of inclination of the orbit to the ecliptic makes any north and south movements unimportant.

26. LIBRATION IN LONGITUDE—The eccentricity of the orbit is quite small for the size of the orbit and therefore any east and west oscillations are inconspicuous.

27. SOLAR RADIATION—.011 of the amount we receive per unit area or about 1/90 as much. This means that the surface which we see and which is entirely composed of clouds must be very cold.

28. ALBEDO—.63. This seems rather high, even greater than that of Jupiter, and may possibly be the result of partial self-luminosity.

29. TEMPERATURE—The temperature of a body which probably possesses heat, as well as receives it, is not easy to determine but a recent estimate sets it at –302°F. This of course is for the surface only and it is too high for solar heat alone so that a local supply is indicated.

30. ATMOSPHERE—The spectrum of Saturn's clouds suggests a deep dense atmosphere but the rings do not seem to possess any.

31. PARALLAX—The horizontal parallax on January 15, 1933 was 0".81 and on July 15, 0".98 of arc. The mean parallax for distance is 0".92 of arc.

32. DISTANCE FROM EARTH—Mean 886,000,000 miles. At nearest opposition it is about 748,000,000 miles and at farthest conjunction 1,024,000,000 miles.

33. DISTANCE FROM SUN—Mean 886,000,000 miles. At perihelion it is about 841,000,000 miles and at aphelion 931,000,000 miles. It might be well to recall here that the mean solar distance of a planet is one-half the major axis of its orbit.

34. SOLAR ASPECT—Seen from Saturn the sun's angular diameter is only 3'22" of arc or a little over 1/9 what it appears to us and only about 1/90 of the area.

35. DIMENSIONS OF ORBIT—The mean diameter of its theoretical orbit is said to be something like 1,772,000,000 miles and its circumference 5,564,100,000 miles but we must remember that the real shape of this orbit is a wide open helix.

36. HELICAL PATH—In this continuous helical journey along with the sun Saturn traverses, during each revolution of 29.46 of our years or one Saturnian year, some 12,621,000,000

miles or about 7,056,900,000 miles more than are given for its theoretical orbit and 1,291,800,000 miles more than the sun during the same period. Keeping up with the sun requires higher speed. See 39.

37. ECCENTRICITY OF ORBIT—.056. The sun is thus out of centre about 45,000,000 miles or a difference of 90,000,000 miles between perihelion and aphelion distances. This is not much for the size of the orbit and will not seriously affect the power of the sun nor the orbital speed of the planet.

38. INCLINATION, ORBIT TO ECLIPTIC—2°30′ of arc. This is a small angle and makes any librations unimportant. The points of intersection are the nodes of the orbit.

39. VELOCITY OF REVOLUTION—In its theoretical orbit it is said to be about 6 miles per second or 21,500 miles per hour but the velocity in its helical path is about 13.5 miles per second and varies only slightly with the eccentricity.

40. MEAN MONTHLY MOTION—In the theoretical orbit it is said to be about 1° of arc or 15,455,800 miles but in its real helical path it actually covers over 35,058,300 miles.

41. PERIOD OF REVOLUTION, SIDEREAL—29.46 of our years or about 10,760 mean solar days. This is the planet's year with some 25,270 of its own days.

42. PERIOD OF REVOLUTION, SYNODIC—Mean 377.5 of our days. As has been said this is the average interval between oppositions or conjunctions as seen from the earth.

43. HELIOCENTRIC LONGITUDE—On January 1, 1933 Greenwich civil time it was 306°20′11″ of arc. The latitude is not given because it is constantly changing and is very small.

44. LONGITUDE OF PERIHELION—This is also a heliocentric position and is 91°44′5″ of arc. Aphelion is opposite and both their latitudes are governed by the inclination of the orbit to the ecliptic.

45. LINE OF APSIDES—This line connects the points just mentioned, is the major axis, divides the orbit into equal parts and advances about 1′ of arc per year, thus very gradually changing the positions of the perihelion and aphelion points.

46. LONGITUDE OF ASCENDING NODE—113°4′16″ of arc. The descending node is opposite but these intersections have no latitude because they are on the ecliptic. See Mercury 46.

47. LINE OF NODES—This imaginary line joins the nodes and divides the orbit into upper and lower portions with respect to the ecliptic.

48. ARC OF RETROGRADE—6° of arc. Retrograde motion is always westward and occurs when the body is nearest the earth. At the beginning and the end of this motion the planet is said to be "stationary" for some time.

49. PERTURBATIONS IN ORBIT—Saturn is influenced most by Jupiter, especially when the latter overtakes him in his orbit. Uranus will influence Saturn slightly when the latter overtakes the former in his orbit.

50. ELONGATION—This as we have seen is the angular distance of a planet from the sun as seen from the earth but for the outer planets it is usually spoken of in terms of items 51, 52 and 53.

51. CONJUNCTIONS—These occur every 377.5 days on the opposite side of the orbit from the earth where the planet is hidden for a time in the intense light of the sun. They occur 12.5 days later each time. Besides these conjunctions with the sun they also occur with the moon and the other planets.

52. QUADRATURE—This occurs twice each year, once on the east and once on the west of the sun as seen by us and always 90° from the sun.

53. OPPOSITION—This is the position of an outer planet when we pass between it and the sun. Like the conjunctions, it is controlled by the synodic period so they happen every 377.5 days, with the same delay of 12.5 days each time.

54. PHASES—These are unimportant because they are always nearly full. See Fig. I.

55. OCCULTATIONS—These are similar to those of Jupiter because the planes of the orbits of the nearer satellites

are almost the same as the planet's equator. The larger ones are frequently occulted and so are stars.

56. TRANSITS—These occur across the disc of the planet for the same reason but are difficult to observe because of the great distance but their shadows can be readily detected on the disc.

57. SATELLITES AND RINGS—Saturn possesses a large family of 10 satellites. The first and largest was discovered by Huygens in 1655 and named Titan. It is of the ninth magnitude, is at a mean distance of about 771,000 miles from Saturn, has a sidereal period of 15 dys. 22 hrs. 41 min. 23 sec., a diameter of 3,000 miles and a mass of .00021 of Saturn. The last and smallest was discovered by W. H. Pickering in 1905 and called Themis. It is of magnitude 17, mean distance 906,000 miles, and has a period of 20 dys. 20 hrs. 24 min. The nearest, called Mimas, is of magnitude 15, is only 117,000 miles distant, has a diameter of 600 miles and revolves in about 22 hrs. 37 min. The farthest, named Phoebe, is of magnitude 17, is distant more than 8,000,000 miles, has a diameter of only 200 miles and revolves backward in a period of 546 days. The five nearest revolve in almost the same plane as their primary, the next two are quite near this plane but the others, excepting Phoebe, are inclined from 10 to 20 degrees. These ten moons together have only six times the volume of ours, while the light available from all that shine on Saturn at any one time is less than 1/100 of what we receive from our full moon. See Observer's Handbook for further details.

Besides these regular satellites, Saturn is surrounded by a remarkable system of rings. These are concentric, flat and very broad and revolve in the plane of the planet's equator, in the same direction and at the same speed. Like the satellites of Jupiter they were first seen by Galileo in 1610 but were not understood until 1655 when Huygens made his observations. The outer diameter of the outside ring is about 172,600 miles and its breadth about 11,000 miles, then there is a space of 2,300 miles called Cassini's division. This is followed by another broader, brighter ring whose outer diameter is about 146,000 miles and its breadth 18,000 miles. Then comes a very narrow division and a third ring of dusky colour having an outer diameter of 110,000 miles and a breadth of 10,900 miles. The dark ring is like a veil through which at times we can see the disc of the planet and its inner edge is about 6,000 miles from the surface of Saturn. The thickness of the rings is probably about 50 miles and they are composed of swarms of meteoric bodies which somehow got into the control of Saturn. On account of their inclination of 26°30′ to the plane of their orbit and 2°30′ more to the plane of the ecliptic these rings apparently open out and close up as the years pass. In 1928 they were at their widest and now they are gradually closing up again, each process requiring 7.5 years. They will be wide open once more in 1943.

58. ECLIPSES—Like the transits these are constantly recurring because, as we have seen, the five nearest satellites revolve in the same plane as their primary. We shall not be able to see them unless their orbits lie in our line of sight.

59. SPECIAL FEATURES—This is the most remarkable and interesting of all the planets. It is the second largest, possesses the most satellites, has the wonderful ring system, is the least dense, the most oblate and probably has still much of its own internal heat. It has captured one comet.

60. HABITABILITY—From what has been said about present conditions on Saturn, it will be apparent that no life as we know it can exist there.

NOTE—For the best times and conditions for observation, see the Observer's Handbook or some good current almanac.

CHAPTER XII.

URANUS.

1. NAME—Uranus means Heaven or Sky. It was the first planet discovered, the others, except Neptune and Pluto, had been known for many centuries. Sir Wm. Herschel discovered it in 1781 and called it Georgium Sidus in honour of the king. Later, at the suggestion of Bode, it was given its present name which is more in keeping with the mythological names of the other planets.

2. MYTH—Uranus was the husband of Gaea, the earth, and father of the Titans. It is said that this god feared his children because some of them aspired to the throne. He therefore confined them in Tartarus from which, under the leadership of Chronos, they finally escaped and drove Uranus from the throne of Olympus.

3. SYMBOL— ⛢ This is a combination of shield and dart designed to replace the H first used in honour of its discoverer.

4. SOUND—Since Uranus was unknown to the ancients, he had no part in the fancied Music of the Spheres but he was always a member of the solar symphony.

5. COLOUR—Uranus is barely visible to the naked eye but in a large telescope it shines with a greenish tint and has darker bands above and below the equator similar to the other large outer planets.

6. MARKINGS—Even in a large telescope it appears as a very small disc and only under the best seeing conditions can the bands be discerned.

7. STELLAR MAGNITUDE—It is of the sixth magnitude and varies only 20 per cent. from opposition to conjunction on account of the small eccentricity and its great distance from us. Some irregularity of surface causes its light to vary during its period of rotation.

8. GREATEST BRILLIANCY—This occurs at opposition during perihelion passage once in a long lifetime.

9. ANGULAR DIAMETER—Mean 3″.8 of arc. This varies but little on account of its great distance. The angular diameter at mean distance is slightly less than that given above.

10. LINEAR DIMENSIONS—Its mean diameter is about 30,400 miles, the polar about 29,000 miles and the equatorial 31,800 miles. This is nearly 4 times that of the earth or 1/28 of the sun and the circumference is about 95,500 miles.

11. AREA OF SURFACE—About 2,702,000,000 square miles or 14 times the earth and 1/870 of the sun.

12. VOLUME—About 14,750,000,000,000 cubic miles or 57 times the earth and 1/23,000 of the sun.

13. MASS—14.6 times that of the earth or 1/23,500 of the sun. It would weigh something like 85 sextillion tons.

14. DENSITY—1.25 times that of water or .23 of the earth and similar to the sun.

15. SURFACE GRAVITY—.9 of the earth so that an object weighing 100 pounds here would weigh only 90 pounds there.

16. FALLING BODIES—During the first second these attain a speed of about 14 feet per second.

17. VELOCITY OF ESCAPE—14.4 miles per second or a little more than twice that of the earth.

18. PERIOD OF ROTATION—This is about 10 hrs. 45 min., although it is not divided into daylight and darkness all round the orbit as is the case with the other planets. See 24.

19. VELOCITY OF ROTATION—This is about 2.5 miles per second or 9,000 miles per hour and thus nearly 9 times that of the earth.

20. DAYS IN ITS YEAR—Ordinarily there would be about 65,400 days but since its equator is greatly tilted there are four peculiar seasons; two polar and two equatorial, but

each very gradually changing into the next as the planet proceeds in its orbital journey. During the polar seasons there is but one day of 21 years for each while during the equatorial seasons there are 16,350 days in each, thus making a total of about 32,700 days in a Uranian year. See 24.

21. MAGNETISM—The high speed of rotation suggests very strong magnetic conditions.

22. OBLATENESS—.09. This indicates a rather large equatorial bulge for the size of the planet.

23. DIRECTION OF AXIS—The writer has not yet learned of this direction but from its inclinations we may say it is possibly somewhere in Taurus.

24. INCLINATION, EQUATOR TO ORBIT—98° of arc. In this case the axis is nearly parallel to the plane of the orbit and thus produces the unusual seasons mentioned above. If we begin when one polar hemisphere is facing the sun it will have a very long cool summertime of 21 years' duration in continual daylight with the small distant sun apparently revolving round the pole while the other polar hemisphere turned from the sun endures an exceedingly frigid winter of the same length and in total continual darkness because the tiny satellites cannot relieve it. As the planet gradually passes from this position the equatorial regions come into the sunlight for 21 years but, unlike the polar hemispheres, they enjoy night and day of about 5 hours each. After 42 years Uranus arrives at the opposite position from the one first considered and the other polar hemisphere has its 21 years of chilly summertime in continual daylight while the other goes into refrigeration and darkness. The planet keeps moving and again the equatorial regions arrive for their long season of short days and nights. How strange.

25. LIBRATION IN LATITUDE—These would be unusual on account of the great inclination if they were visible.

26. LIBRATION IN LONGITUDE—The small eccentricity will preclude the possibility of any visible east and west oscillations.

27. SOLAR RADIATION—.003 or 1/333 of our supply

per unit area. This is very small because of its great distance from the sun and yet it amounts to 700 times as much as our full moon sends us.

28. ALBEDO—.63. This is the same as Saturn but the great distance and small diameter make it difficult to observe and measure.

29. TEMPERATURE—About–340° F. Like the other large planets, Uranus must still be highly gaseous and while the cloud surface must be very cold the actual surface may receive considerable heat from internal sources.

30. ATMOSPHERE—The high albedo indicates a dense cloud-laden atmosphere similar to the other bright planets, and the possession of an unknown element evidently produces the beautiful greenish tint we see on its cloud surface.

31. PARALLAX—The mean parallax from which its distance is computed is about 0″.45 of arc.

32. DISTANCE FROM EARTH—Mean about 1,782,-300,000 miles. At nearest opposition it is about 1,605,800,000 miles and at farthest conjunction 1,959,800,000 miles.

33. DISTANCE FROM SUN—Mean about 1,782,300,000 miles. At perihelion it is about 1,698,800,000 miles and at aphelion 1,866,800,000 miles. This is just a little more than 20 times our distance from the sun.

34. SOLAR ASPECT—As seen from Uranus the angular diameter of the sun is only 1′40″ of arc, or twice that of Venus.

35. DIMENSIONS OF ORBIT—The mean diameter of the theoretical orbit is given as 3,564,600,000 miles and the circumference 11,203,000,000 miles but the real path is a very wide open helix.

36. HELICAL PATH—In this continuous helical journey along with the sun Uranus traverses, during each revolution of 84 of our years or one Uranian year, some 35,383,000,000 miles or about 24,183,000,000 miles more than are given for its theoretical orbit and 1,846,000,000 miles more than the sun during the same period. To cover these greater distances requires higher speed than given for the plane orbit. See 39.

37. ECCENTRICITY OF ORBIT—.047. The sun is thus out of centre about 84,000,000 miles or a difference of 168,000,000 miles between perihelion and aphelion distances. This is so small that it does not alter the planet's speed or its distance from the sun sufficient for ordinary observation to detect.

38. INCLINATION, ORBIT TO ECLIPTIC—Only 46′ of arc. This is the least of all and therefore it is in almost the same plane as the ecliptic and the earth's orbit. If now we recall the other inclination of 98° we see that the planet with its moons appears as a windmill presenting its face, its back and its edge to us at different stages in its revolution. See Fig. VII. The nodes are at the intersections of the orbit and ecliptic.

39. VELOCITY OF REVOLUTION—In the theoretical orbit it is said to be about 4 miles per second or 14,400 miles per hour but the velocity in its real helical path is over 13 miles per second.

40. MEAN MONTHLY MOTION—In its theoretical orbit it is said to be about 21′ of arc or 10,895,000 miles but in its real path it actually covers over 34,418,000 miles each month.

41. PERIOD OF REVOLUTION, SIDEREAL—84.02 of our years or about 30,680 days and about 7 times as long as Jupiter. This is its year of four unusual seasons, each 21 earth years in length.

42. PERIOD OF REVOLUTION, SYNODIC—Mean 369 of our days. It is the time it takes the earth to leave Uranus at opposition, make a revolution and catch up with him again at the next opposition.

43. HELIOCENTRIC LONGITUDE—On January 1, 1933 Greenwich civil time it was 22° 14′12″ of arc. The latitude is always changing. See Mercury 43.

44. LONGITUDE OF PERIHELION—169°34′41″ of arc. Aphelion is opposite and both are heliocentric positions. Their latitudes are governed by the inclination of the orbit to the ecliptic.

45. LINE OF APSIDES—This joins the above points, is the major axis of the orbit, and divides the orbit into equal parts.

46. LONGITUDE OF ASCENDING NODE—73°39′22″ of arc. The descending node is opposite but they have no latitude because they are on the ecliptic.

47. LINE OF NODES—This joins the nodes and divides the orbit with respect to the ecliptic. The portion from about 73° round to 253° being above the ecliptic. See Fig. 6.

48. ARC OF RETROGRADE—4° of arc. This is about the same as its advance in revolution but it does not mean that the planet is losing as much as it gains for the retrograde motion is only apparent.

49. PERTURBATIONS IN ORBIT—Uranus suffers occasional perturbations on account of the attraction of Neptune whenever the former approaches the latter is their orbital relations. This was carefully estimated by Adams and Leverrier and led to the discovery of Neptune. There is also the long inequality with Jupiter and the influence of Saturn to be taken into account.

50. ELONGATION—This is the angular distance of Uranus from the sun as seen by us but it is usually expressed in terms of the three following items.

51. CONJUNCTIONS—These occur every 369 days on the opposite side of the orbit from the earth when the planet is hidden in the sun's brilliant light. They also occur with the moon and the other planets.

52. QUADRATURE—This occurs twice each year east and west of the sun and always at an angle of 90° at the earth.

53. OPPOSITION—This also occurs every 369 days when we pass between the planet and the sun but 3 and 3/4 days later each time.

54. PHASES—These are of very little importance because the gibbous phase is very broad and we see it as full.

55. OCCULTATIONS—These cannot occur except when the earth passes through the line of nodes of the satellites, because of the unusual inclinations which make it possible for us to see the satellites throughout almost their entire revolutions around Uranus.

56. TRANSITS—The satellites are so small and the opportunities to view them so rare that they are almost impossible and quite valueless for us.

57. SATELLITES—Uranus has a retinue of four tiny moons which, on account of the great inclination of the axis, revolve backward during half of each Uranian year and in almost the same plane as the planet's equator. When the earth passes through their line of nodes their orbits appear edgewise and almost vertical. This occurred in 1924 and will occur again in 1966 but in between they will gradually open to our view until 1945 when they will be wide open. These moons were discovered by two English astronomers, Sir Wm. Herschel and Wm. Lassell. In 1787 Herschel, who had previously discovered Uranus, found the two larger and outer ones and called them Oberon and Titania. The former has an estimated diameter of 800 miles, a distance of about 365,000 miles from Uranus, and a sidereal period of 13 days 11 hours. The latter has a diameter of perhaps 1,000 miles, a distance of about 273,000 miles, and a period of 8 days 17 hours. In 1851, about sixty-four years later, Lassell found the two smaller and nearer ones and named them Umbriel and Ariel. The former has a diameter of about 400 miles, a distance of about 167,000 miles, and a period of 4 days 3.5 hours. The latter has a diameter of perhaps 500 miles, a distance of about 120,000 miles, and a period of 2 days 12.5 hours.

58. ECLIPSES—These, like the transits and occultations are exceedingly rare and inconspicuous for us.

59. SPECIAL FEATURES—The strange element in its atmosphere, the apparent part-time backward rotation of the system, the unusual inclination of the planet's axis and the peculiar seasons. It has captured two comets.

60. HABITABILITY—While this planet would be more interesting to live on than even Saturn, we cannot think of it as habitable.

NOTE—Seeing Uranus with the naked eye may be a good eye test but one needs a good telescope to appreciate its proper appearance. See the Observer's Handbook for the best opportunities for observation.

CHAPTER XIII.

NEPTUNE.

1. NAME—The word Neptune is probably from the Latin napta meaning moist and pertaining to water and the sea. The Greeks called it Poseidon and worshipped him in many cities and on many shores, especially at Corinth where the Isthmian games were held in his honour. Before Neptune was discovered in 1846, its position was calculated by Adams of Cambridge and sent to the Astronomer Royal who carelessly failed to make the search. Meanwhile, Leverrier of Paris had also determined its position and sent it to Galle at Berlin who immediately made the search and found it within a degree of the mathematical location given. These calculations were based on the perturbations of Uranus caused by the unknown planet and constitute one of the greatest astronomical triumphs of all time.

2. MYTH—When Jupiter and his brothers, including Neptune, overthrew their parents, the Titans, Neptune and his wife Amphitrite, parents of the Cyclops, succeeded to the rule of the sea in place of Oceanus and Tethys. He is said to have domesticated the horse and to have given his own steeds, which were the waves, golden manes and bronze hoofs with which to draw his rumbling chariot over the sea.

3. SYMBOL—♆ A trident fashioned like the three-pointed harpoon of the Aegean fishermen. With this strange instrument, at once a weapon and a wand, he is said to have shattered rocks and summoned or silenced the most terrific storms on land or sea.

4. SOUND—Like Uranus, this planet was unknown to the ancients and so played no part in the so-called Music of the Spheres.

5. COLOUR—Neptune cannot be seen with the naked eye but in a good telescope we see it as a small indefinite disc glowing with a greenish tint similar to that of Uranus.

6. MARKINGS—Because of the great distance and the small diameter, as well as the limits of our present instruments, no permanent features have yet been seen.

7. STELLAR MAGNITUDE—7.6 at opposition. This is too small to be seen with much satisfaction, even in a large telescope.

8. GREATEST BRILLIANCY—When opposition and perihelion passage are reached at the same time. This will not occur for more than 100 years.

9. ANGULAR DIAMETER—Mean 2″.5 of arc. The variation of this angle is small on account of the great distance from the sun and the small eccentricity of the orbit. The angular diameter at mean distance is about the same.

10. LINEAR DIMENSIONS—The mean diameter is about 32,000 miles or a little over 4 times that of the earth and 1/27 of the sun. The circumference is about 100,000 miles. In their relative sizes Neptune and Uranus are much more like twins than are the earth and Venus.

11. AREA OF SURFACE—About 3,215,000,000 square miles or over 16 times the earth and more than 1/730 of the sun. Like the other large planets it is still in a very gaseous condition.

12. VOLUME—17,160,000,000,000 cubic miles or about 66 times the earth and 1/19,300 of the sun.

13. MASS—About 17 times the earth or nearly 102 sextillion tons.

14. DENSITY—1.3 times water or .236 of the earth and similar to the other large planets and the sun.

15. SURFACE GRAVITY—.94 of the earth and a little stronger than Uranus.

16. FALLING BODIES—These attain a velocity of about 15.75 feet per second during the first second.

17. VELOCITY OF ESCAPE—12.95 miles per second or somewhat less than twice that of the earth.

18. PERIOD OF ROTATION—According to the latest spectroscopic determination it is probably about 15 hrs. 48 min. so there are a little less than 8 hours daylight and 8 hours darkness each Neptunian day, but the unusual angle of inclination stands it almost upside down and makes it appear to rotate in a backward direction.

19. VELOCITY OF ROTATION—About 1.76 miles per second or 6,330 miles per hour and 6 times as fast as the earth.

20. DAYS IN ITS YEAR—About 91,320 in each revolution, due to its speed of rotation and its great orbit or path.

21. MAGNETISM—This will be similar to Uranus and like it must wait for further investigation.

22. OBLATENESS—Said to be .02 which is a very low ratio and if true would mean a small polar flattening and equatorial bulge.

23. DIRECTION OF AXIS—The writer has not yet learned about the axial direction of this inverted planet. See Fig. VII.

24. INCLINATION, EQUATOR TO ORBIT—151° of arc. This is a very large obtuse angle which turns the planet nearly upside down and produces four seasons similar to those of the earth but exceedingly cold and each some 41 of our years long.

25. LIBRATION IN LATITUDE—These are so very small and at such a great distance that they have little interest for us.

26. LIBRATION IN LONGITUDE—These also will be without interest because of the small eccentricity and the great distance.

27. SOLAR RADIATION—About .0011 or 1/900 of the amount we receive per unit area and equal to only about as much light as we might get from 500 full moons. Sunlight reflect-

ed from Neptune reaches us in about 4.25 hours but light from the nearest star Alpha of the Centaur takes about 4.25 years.

28. ALBEDO—.73. This puts it in the highest class with Venus and Jupiter and indicates a dense cloud-laden atmosphere like the larger planets.

29. TEMPERATURE—At the surface it is said to be about −364° F. but as in the case of some of the other outer planets, the lack of solar heat may be made up from internal supplies.

30. ATMOSPHERE—The spectrum shows bands similar to those of the other larger planets but stronger and, as in the case of Uranus, the presence of a strange element probably accounts for the greenish tint we observe. Perhaps the clouds are carbon dioxide.

31. PARALLAX—The mean parallax from which its distance is computed is about 0″.29 of arc.

32. DISTANCE FROM EARTH—Mean about 2,782,700,000 miles. At nearest opposition it is about 2,651,800,000 miles and at farthest conjunction about 2,933,700,000 miles.

33. DISTANCE FROM SUN—Mean about 2,782,700,000 miles. At perihelion it is about 2,744,700,000 miles and at aphelion about 2,840,700,000 miles.

34. SOLAR ASPECT—The sun's angular diameter as seen from there is about 1′4″ of arc and it would look something like Venus to us.

35. DIMENSIONS OF ORBIT—The mean diameter of the theoretical orbit is said to be about 5,565,400,000 miles and the circumference about 17,555,000,000 miles but the real path is an exceedingly open helix.

36. HELICAL PATH—In this continuous helical journey along with the sun Neptune traverses, during each revolution of about 165 of our years or one Neptunian year, some 67,820,000,000 miles or about 50,265,000,000 miles more than are given for its theoretical orbit and 2,315,400,000 miles more than the sun during the same period. These greater distances require higher speed. See 39.

37. ECCENTRICITY OF ORBIT—.0085. The sun is thus out of centre about 48,000,000 miles or a difference of 96,000,000 miles between perihelion and aphelion distances. This is very small compared to the size of the orbit so that it is almost circular and the seasons will not be affected by the very slight variation of sunlight.

38. INCLINATION, ORBIT TO ECLIPTIC—1°47′ of arc. This is quite close to the plane of our orbit and the ecliptic so that in spite of the inversion of the planet and its apparent backward rotation it is situated with respect to the sun quite like our own planet.

39. VELOCITY OF REVOLUTION—In the theoretical orbit it is given as 3.4 miles per second or 12,200 miles per hour but in its real helical path it is about 12.9 miles per second.

40 MEAN MONTHLY MOTION—In the theoretical orbit it is said to be about 11′ of arc or 8,860,000 miles but in its helical path it actually covers over 34,250,000 miles each month.

41. PERIOD OF REVOLUTION, SIDEREAL—164.78 of our years or about 60,180 earth days. This is nearly twice as long as Uranus and almost 14 times that of Jupiter. Neptune has covered only a little more than half its orbit since it was discovered in 1846.

42. PERIOD OF REVOLUTION, SYNODIC—Mean 367.5 of our days or slightly over one year so that we can observe it for many months each year.

43. HELIOCENTRIC LONGITUDE—On January 1, 1933 Greenwich civil time it was 158°27′52″ of arc. The latitude is always changing so we do not give it. See Mercury 43.

44. LONGITUDE OF PERIHELION—44°2′42″ of arc. Aphelion is opposite. Their latitudes are governed by the inclination of the orbit.

45. LINE OF APSIDES—This joins the above points, is the major axis of the orbit and divides it into two equal parts.

46. LONGITUDE OF ASCENDING NODE—131°2′30″ of arc. The descending node is opposite but they have no latitude because they are on the ecliptic.

47. LINE OF NODES—This joins the nodes and divides the orbit with respect to the ecliptic but not into equal parts.

48. ARC OF RETROGRADE—About 3° of arc. This apparent reverse motion continues for about four months and the planet seems to be stationary at the beginning and the end of the arc.

49. PERTURBATIONS IN ORBIT—As we have previously remarked, Neptune causes perceptible perturbations of Uranus and also Pluto. Neptune is influenced by both of them and he will be lifted by Pluto when they arrive abreast at and near Pluto's perihelion.

50. ELONGATION—As remarked above, this is the angular distance of a planet from the sun as seen by us but for the outer planets it is usually expressed in terms of the three following items.

51. CONJUNCTIONS—These are unimportant for us because of the planet's great distance. They occur every 367.5 days or just about annually on the opposite side of the sun from us and may also take place with the moon and the other planets.

52. QUADRATURE—This occurs twice each year, one east and the other west of the sun and at right angles to a line joining the earth and the sun.

53. OPPOSITION—This occurs when we pass between the sun and the planet every 367.5 days but about two days later each time.

54. PHASES—These are of no importance to us because they are so distant and always almost full.

55. OCCULTATIONS—These are rare because of the angle of the orbit of the satellite and are unimportant because of the great distance which separates us from Neptune.

56. TRANSITS—These are also very rare and without interest to us.

57. SATELLITES—Neptune, like the earth, has but one moon, Triton, thus far discovered and this was found by Lassell within a month after the discovery of the planet. Its orbit is

almost circular with a radius of 220,000 miles and a period of 5 dys. 21 hrs. 2 min. The inclination of its orbit to that of its primary is about 145° and it revolves in a backward direction. Its magnitude is between 13 and 14, its mass about half that of Mars and its diameter about the same as our moon.

58. ECLIPSES—These, like some of the other items, are very rare and unimportant for us because of the distance and the angle of the orbit of the satellite.

59. SPECIAL FEATURES—Among these are its unique discovery, its retrograde rotation, its peculiar element, its very unusual inclination, its high albedo and its family of six comets.

60 HABITABILITY—Life as we know it could not exist on a planet so far from the sun.

NOTE—Neptune had held the frontier of the Solar System for 84 years but recently that honour was passed on to another, the newly discovered Pluto. Thus Neptune was chief sentry for only half his year or a single year of Uranus.

CHAPTER XIV.

PLUTO.

1. NAME—Among the Greeks his name was Dis, the god of the under-world. The Romans called him Pluto, the ruler of Tartarus and brother of Jupiter and Neptune. The new planet's probable position and orbit were calculated more than fifteen years ago by Percival Lowell at his observatory near Flagstaff, Arizona. Following these calculations, a diligent search was made both of the sky and photographic plates until it was found not far from the star Delta of Gemini in March, 1930. The name, suggested by a child in England, seems very appropriate and its letters are here proposed as the first letters of Percival Lowell, unusual telescopic observer. The name must not be confused with Plutus, the god of wealth.

2. MYTH—The best known story about Pluto is that which tells of his abduction of Proserpina, the beautiful daughter of Ceres, whom he carried off to Tartarus to be his wife.

3. SYMBOL—The original was a curious cap given to him by the Cyclops with which he could make himself invisible at any time. This does not lend itself very well to astronomical symbolism so we suggest that the permanent symbol be a circle surrounding the X which designated it before it was named.

4. SOUND—Like Uranus and Neptune it played no part in the Music of the Spheres but with them it has always been a member of the solar symphony.

5. COLOUR—It was rather strange to find a so distant planet with a yellowish tint something like Mercury. It must be older than Tartarus.

6. MARKINGS—Thus far no markings have been seen and we may not expect to discover any until much better instruments are available.

7. STELLAR MAGNITUDE—This is between 14 and 15 and means that we shall not see it except with a very good telescope.

8. GREATEST BRILLIANCY—This will occur at perihelion where it will arrive in about 60 years and be about 700,000,000 miles nearer than its occasional neighbour, Neptune.

9. ANGULAR DIAMETER—This has been set at about 0″.5 of arc. The variation will be larger than any other planet because of the great eccentricity of the orbit. The angular diameter at mean distance will be about the same.

10. LINEAR DIMENSIONS—From the angular measure above its diameter is about 9,160 miles and its circumference 28,800 miles. Some think it is only about half this amount.

11. AREA OF SURFACE—From the above diameter it is about 262,200,000 square miles.

12. VOLUME—About 403,500,000,000 cubic miles or more than half as large again as the earth.

13. MASS—It is estimated as similar to the earth.

14. DENSITY—Estimated at about 4 times that of water or a little less than the earth.

15. SURFACE GRAVITY—Probably slightly more than 4/5 of that of the earth.

16. FALLING BODIES—These attain a speed of about 12 feet per second during the first second.

17. VELOCITY OF ESCAPE—Possibly about 5 miles per second.

18. PERIOD OF ROTATION—Possibly about 20 hours but this is only a guess.

19. VELOCITY OF ROTATION—Possibly about 1,400 miles per hour and retrograde.

20. DAYS IN ITS YEAR—Possibly about 108,700 unless it should be inclined like Uranus.

21. MAGNETISM—Possibly similar to the earth but who will find out for us?

22. OBLATENESS—Possibly similar to the earth but we must wait for the facts.

23. DIRECTION OF AXIS—Possibly inverted.

24. INCLINATION, EQUATOR TO ORBIT—Possibly perpendicular.

25. LIBRATION IN LATITUDE—Unimportant.

26. LIBRATION IN LONGITUDE—Unimportant.

27. SOLAR RADIATION—This is only about 1/1,600 of the amount we receive per unit area.

28. ALBEDO—About .45 or only 2/3 of the average of the larger planets.

29. TEMPERATURE—At the surface it may be about -400° F.

30. ATMOSPHERE—Since it is yellow and has a low albedo, its atmosphere may be rare like that of Mars.

31. PARALLAX—The mean parallax is about 0″.22 of arc and from it we compute the distance.

32. DISTANCE FROM EARTH—Mean about 3,780,000,000 miles. At nearest opposition it is 2,717,000,000 miles and at farthest conjunction 4,843,000,000 miles.

33. DISTANCE FROM SUN—Mean 3,780,000,000 miles. At perihelion it is about 2,810,000,000 miles and at aphelion 4,750,000,000 miles. This is about 40 *times that of the* earth and a little more than 100 times that of Mercury.

34. SOLAR ASPECT—The angular diameter of the sun varies greatly on account of the unusual eccentricity of the orbit. It will appear about as Sirius does to us.

35. DIMENSIONS OF ORBIT—The mean diameter of its theoretical orbit is said to be about 7,560,000,000 miles and its circumference about 23,760,000,000 miles but the actual path is an enormously open helix almost approaching a straight line.

36. HELICAL PATH—In this continuous helical journey with the sun Pluto traverses, during each revolution of about 248 of our years or one Plutonian year, some 101,422,000,000 miles or about 77,660,000,000 miles more than are given for its theoretical orbit and 2,800,000,000 miles more than the sun during the same period. This requires higher speed than given for the plane orbit. See item 39.

37. ECCENTRICITY OF ORBIT—.25. This is the greatest of all and amounts to 945,000,000 miles or a difference of about 1,890,000,000 miles between perihelion and aphelion distances. At perihelion the orbit lies within that of Neptune but the angle of inclination is so great that Neptune cannot crash into Pluto and really passes quietly about 240,000,000 miles be neath it.

38. INCLINATION, ORBIT TO ECLIPTIC—17°9′ of arc. This is the greatest of all and is the angle which prevents any collisions. The points of intersection are the nodes.

39. VELOCITY OF REVOLUTION—In the theoretical orbit it is given as about 3 miles per second or 10,800 miles per hour but the velocity in its real helical path is about 12.8 miles per second. This is only 1/5 of a mile per second faster than the sun and makes it look as if any more trans-Neptunian planets are nearly impossible.

40. MEAN MONTHLY MOTION—In its theoretical orbit it is said to be about 7′ of arc or 7,984,000 miles but in its proper helical path it actually covers over 34,080,000 miles each month.

41. PERIOD OF REVOLUTION, SIDEREAL—248 of our years or about 90,500 days. Two revolutions of Pluto almost equal three of Neptune. They were quite close to each other in 1892 but since that Neptune has been steadily leaving Pluto behind and will not catch up with it again for 486 years.

42. PERIOD OF REVOLUTION, SYNODIC—This is very close to one year because Pluto moves so little during that period and the earth has only a degree and a quarter extra to catch up to Pluto.

43. HELIOCENTRIC LONGITUDE—On January 1,

1933 Greenwich civil time is was 132°2′ of arc. The latitude is not given because it is always changing.

44. LONGITUDE OF PERIHELION—222°31′ of arc. Aphelion is opposite and their latitudes are governed by the inclination of the orbit.

45. LINE OF APSIDES—This joins the above points, is the major axis of the orbit and divides it into equal parts.

46. LONGITUDE OF ASCENDING NODE—109°22′ of arc. The descending node is opposite but they have no latitude because they are on the ecliptic.

47. LINE OF NODES—This joins the nodes and divides the orbit with respect to the ecliptic but not into equal parts.

48. ARC OF RETROGRADE—Not reported.

49. PERTURBATIONS IN ORBIT—These are caused by Neptune and Uranus whenever they approach Pluto in their orbital relations and were the chief basis for calculating its probable position.

50. ELONGATION—Not reported.

51. CONJUNCTIONS—At the somewhat recent rather distant conjunction with Neptune they were about 1,765,000,000 miles apart. The last close conjunction occurred about 10,000 years ago and the next will take place in about 30,000 years. They also occur with the moon and the other planets.

52. QUADRATURE—As with the other planets.

53. OPPOSITION—As with the other planets.

54. PHASES—They are of very little interest.

55. OCCULTATIONS—Without interest for us.

56. TRANSITS—Likewise of little interest.

57. SATELLITES—None yet discovered.

58. ECLIPSES—Of no particular interest.

59. SPECIAL FEATURES—Too early to tabulate.

60. HABITABILITY—Wholly improbable.

NOTE—Watch for information.

CHAPTER XV.

COMETS AND METEORS.

As in the case of the planetoids, we shall not follow the numbered items closely but only as our information requires.

COMETS.

These differ in many ways from the planets and one should hardly think of associating them but for the fact that they also revolve round the sun in definite periods. Whatever they are when far out in space, we call them Comets when they have been captured by the sun and made to travel in long elliptical paths round it. On their way in or out many have been affected by the attraction of the outer planets and made to trace shorter elliptical paths whose aphelia are not far from the planet's orbit. The general name comes from coma, meaning hair, while the special names are given to them according to the year and the discoverer's name, although the computer's name sometimes takes the place of the latter, as in the case of Halley and Encke. When the orbit has been fully determined they receive their final number and a letter to differentiate them from others of the same year. In 1925 eleven were designated in these ways and it was a record. During almost any clear night with a good telescope one may see perhaps a dozen. About 1,000 have been found and designated.

Their colour is usually yellowish but occasionally a greenish tint is seen in their tails.

On close examination the head appears to be composed of a nucleus with a surrounding envelope of illuminated gas which is sometimes in layers. Their structure seems to be a loosely compacted mass of meteoric matter, the lighter particles of which are transformed into a tail by radiant repulsion when they approach the sun. The nucleus may also change its arrangement at that time.

Comets have unusual dimensions. The diameters of the heads vary from a few miles to hundreds of thousands of miles and some have even reached the million mark. The nuclei are also extensive, ranging from a few miles to the size of the earth.

The tails are exceedingly extensive and grow from hundreds to millions of miles in width while their length has been known to reach over one hundred million miles and always in the direction away from the sun. Some of the smaller ones have had no tails at all and occasionally small tails are attracted toward the sun.

The masses are very small and no perturbations caused by them have been measurable. The appreciable densities pertain to the nuclei alone as no matter how large the head and tail they never diminish the visibility of stars beyond them. In 1910 Halley's comet transited the sun and, although we had to look lengthwise through the tail, head and nucleus, nothing of it could be seen.

Their light is mainly reflected sunlight but the nucleus may possess some light of its own.

The eccentricity of their orbits is very great, so that their perihelion distances vary from about 465,000 to 375,000,000 miles but few exceed 140,000,000 miles.

Their inclinations are at many angles although some are in groups at very similar angles and may be parts of a former larger comet broken up by many visits to the sun. A few have been known to do so and disappear perhaps to become meteors.

Their average velocity of revolution varies from 300 to 400 miles per second and their speed at perihelion is naturally very high.

Their sidereal periods vary from about 3 years to as much as 10,000 years, some even following a retrograde course.

Three comets have been called great. The first appeared in 1744 with two tails and then gradually developed six. The second in 1811 with a tail 15,000,000 miles in diameter and 100,000,000 miles in length. It was visible from March to August of the next year and its period was said to be about 3,000 years while its aphelion distance was given as 14 times that of Neptune. The third appeared in 1843 and was remarkable for its close approach to the sun, which was only 500,000 miles. Its tail was 2,500,000 miles wide and 164,000,000 miles long. The writer clearly remembers his childish delight and wonder at seeing the very large comet of 1882.

METEORS.

These are undoubtedly residual cosmic matter that was not included in any of the planets and, like the planetoids, was divided and forced into the present orbits by the powerful attraction of the larger planets. Their number is probably inconceivable and we are told that the earth is passing through a constant rain of them amounting to many millions each day. Most of them cannot be seen with the naked eye and many small ones streak the camera plates set up for other work. They vary in size from mere specks that flash for only a moment to those which weigh several tons and produce long brilliant paths through the air when they plunge to earth and become meteorites.

The best displays may be seen at special times according to their positions in their orbits with reference to the earth. Their centres of dispersion or radiant points are said to be in the constellations from whose direction they appear to come but they are our near neighbours and have nothing whatever to do with the stars. The best known groups or showers are: the Andromids from November 17 to 27 in a period of 6.6 years, the Leonids of November 14 and 15 in a period of 33.3 years, the Perseids of August 10 in a period of 120 years, and the Lyrids of April 20 in a period of 415 years.

Their velocities in outer space are said to be between 20 and 40 miles per second and that when they overtake the earth their speed is reduced by the amount of its orbital motion so that they travel at only about 7 or 8 miles per second and when they meet the earth their speed is increased by the same amount so that they travel at between 50 and 60 miles per second. This accounts for the intense heat and blinding light generated by their frictional contact with our atmosphere.

The brilliant meteors and fire balls may be from 80 to 100 miles high but the smaller so-called shooting stars are usually from 50 to 80 miles up in the air. Most meteorites fall into the large water areas of the earth and are lost. Those which fall on the land sometimes dig themselves in so deeply that they also are lost but those seen on arrival are sought with great enthusiasm by collectors. Their appearance when found is always unusual and is described as rough, angular, pitted, black, partly glazed and if iron, magnetic.

Careful analysis has revealed the presence of 30 of the known elements, the most common being iron and nickel and alloys of these.

Many fine specimens are now in the foremost museums and the most important are: the Williamette of Oregon, weighing about 15 tons, mostly stone and now in the American Museum at New York; the Greenland, secured by Commander Peary for the same institution and weighing about 36 tons; the Mexican, called Bacubirito, weighing about 50 tons; the South African, mostly iron and weighing about 60 tons; the Australian, which dug a crater 120 by 220 yards; the Afghan, which dug another large hole in Central Asia; the Siberian, which fell in 1908; the one recently discovered in Central Africa between Lakes Nyassa and Tanganyika; and the great American of Arizona, buried in a crater 3/4 of a mile in diameter and about 500 feet deep.

THE MODEL PLANETARIUM.

1. ITS NATURE AND PURPOSE—The planetarium illustrated in our frontispiece is a simple modern device with which one can explain and demonstrate the more important motions, positions, relations and configurations of the planets and satellites in their theoretical orbits round the sun. With this instrument and the author's Handbook of the Solar System one needs no other equipment to illustrate this very interesting part of astronomical study.

2. ITS DESIGN AND CONSTRUCTION—In planning this instrument we were fully aware that numberless attempts had already been made to supply the long-felt need of a satisfactory demonstrating device. We also knew that nearly all of them were involved, expensive, mechanical contrivances in which the baffling matter of proportion played a disconcerting part. We therefore sought simplicity, adequacy and presentability by eliminating all wheels, belts and curious mechanical methods. We abandoned exact proportion and chose rather to merely suggest it because it can be easily explained.

The mechanism therefore is extremely simple and is composed of a central hub wired for hydro round which, on wire arms, the planets may be revolved at will, the planets themselves are free to rotate and their axes also may be turned during each revolution to maintain the proper direction of the poles and the relation of their equators to the ecliptic.

The small horizon disc on the model earth is set at north latitude 45° but it may have to be removed and attached higher or lower according to the latitude of the operator. Its purpose is to represent the local horizon plane and when thought of as reaching the sky all round serves to define the visible area of the sky at any time as seen from its centre and also the place of sunrise and sunset, as well as the rising and setting of the moon and planets.

The graduated circle beneath the sun is set with the vernal equinox "O" to the east and shows the months and seasons of the earth. It is divided into degrees for finding heliocentric positions. The graduated circle beneath the earth is for setting the other planets in their right ascensions each month and for indicating the direction of the constellations of the zodiac in which they are to be found. It is divided into hours and minutes for this purpose.

3. ITS ADJUSTMENT AND OPERATION—Stand the instrument plumb and facing north, connect an extension cord and plug in.

Release the wing-nut, tilt the hub until it leans north about 23.5 degrees and tighten the nut. This will set the system ready for study.

Move the earth arm round until it comes to the middle of the current month on the sun circle and rotate its axis until its pole points directly north to Polaris. This direction of the earth's axis must be carefully maintained so as to show the changing seasons and the changing relation of the equator to the ecliptic. Now rotate the earth until the horizon disc comes to its proper position in relation to the sun for the hour of study.

Place the moon in its orbit according to the phase given in any almanac or calendar for the current month and the hour of study.

Look up the R.A. for each of the other planets and by reference to the earth circle set them where they belong for the middle of the current month.

Consult a book almanac or the Observer's Handbook for the configurations of Jupiter's satellites and place them in their apparent positions as seen from the earth at the hour of study. The actual orbital positions are not given because they change so rapidly.

Now, in imagination, take your place as a tiny observer on the model earth at the centre of the horizon disc and look around at the planets which are above this plane. If you wish the model planets to approximate the positions of the planets in the outside sky, where by reason of the changing relation of the equator to the ecliptic they are higher or lower, just tilt the hub the necessary amount.

These positions are for midnight, so if one wishes to study at an earlier hour it is necessary to set the planets 15 degrees for each such hour behind the positions given.

The direction of the axis of each planet must be maintained the year round for the purpose previously mentioned. Their proper directions are: the earth, directly north; Saturn and Uranus, north-eastward; Mars, eastward; Mercury, Venus and Jupiter, upright; Neptune, Pluto,

The present precessional positions of the constellations of the zodiac are as follows:

> The fish and the ram and the bright-eyed bull,
> The twins and the crab and the lion cruel,
> The maid and the scales and the scorpion,
> The archer, the goat and the waterman.

Be sure and try to demonstrate as many of the items as you can from the data in the Handbook of the Solar System.

DIANA'S RETURN.

W. G. C.

I've read in books, said Mother Earth,
  My daughter's coming home;
But when and how are Greek to me,
For though I read I cannot see
How men can tell her perigee,
  Say naught of when she'll come.

Astronomers are busy folks,
  Forever watching us;
Collaborating nights and days
About this old world and her ways,
About Diana's golden phase;
  Enough to make us cuss.

How do they know, how can they tell
  Such things may come to pass?
Great calculations they prepare,
With telescopes they watch her there
And measure by a spider's hair;
  There's no escape, alas.

But if she's coming as they say,
  Within a billion years;
I wonder if she'll stop and fret
About the limit Roche has set,
Or will she crash in fervent heat,
  That solid frame of hers.

'Tis fifty million years or more
  She's been away, you see,
Torn by a solar tidal wave,
Snatched from the ocean's mighty cave,
And held in chains just like a slave
  'Twixt yonder sun and me.

And when she comes, I'll take her to
  That self-same spot again—
There she may sit upon my knee,
'Tween Golden Gate and Yellow Sea,
Where sunsets reach eternity
  That haunts the souls of men.

Though caught by stealthy thieves of space,
  She ne'er forgot her home;
But ever turned this way and smiled,
Just like a good obedient child,
And on my shores the tides uppiled,
  Though still compelled to roam.

The years have gone, the journey's done,
  Diana's home at last;
Through many a thousand leagues she hied,
With many a javelin in her side,
Flung by the fiery Sol who cried,
  I'll follow just as fast.

But what, my child, are all these marks?
  These blotches, pocks and spires?
Ah, Mother dear, I went alone
Through storms of flame and flying stone,
With fulminations of my own,
  Against those cosmic fires.

Alas, alas, I feel so strange
  Since you came back to me;
When in my arms I clasp your weight,
I feel I surely can't rotate
On tiptoe as I did of late.
  What must the reason be?

. . . .

The answer is not hard to guess,
  For when the Moon sits down,
There'll be a shock to Mother Earth
Like in the hour of Phoebe's birth,
And all around her giant girth
  A trembling to her crown.

Old Mother Earth with awful groan
Will know her course is run;
She'll roll and wabble without aim
As solar forces grip her frame,
Only at last to yield in shame
A captive of the sun.

The Moon will swell the Sea of Peace,
But peace will then be gone;
Five thousand fathoms deep she'll sink,
And all the creatures on Earth's brink
Of Noah's flood will quickly think,
And seek a safety zone.

But though she sinks so far below,
She's high above the foam;
Above the waves, above the crowds,
Beyond the air our planet shrouds,
Two thousand miles above the clouds
She rears her sunkissed dome.

And so the continents will change,
The shorelines be renewed;
While round the Moon on every hand
Three thousand miles of water stand,
And make the widening seascape grand
From every angle viewed.

For many a mile her swelling bilge
Will overhang the sea;
Full many a score of miles away
Her darksome shadow hold its sway
And make a night within the day,
O'er limpid lake and lea.

And then the eyes of all the world
Will focus on the sight;
The scientists all wide awake
Will go to see this fact or fake
And many a picture draw and take
To ponder through the night.

With speedy craft they'll fill the sea,
The ships with eager men;
But as they reach that arid strand,
They'll find no shore on which to land,
No harbour fit for ships to stand,
So they'll return again.

The airmen then like gulls will seek
A place to disembark,
But ever and anon they'll fail,
Their efforts seem of no avail,
They never, never can assail
That rugged ceiling dark.

Ah, what's the use, all say at last,
Attempting such a chore?
Let's go back home to plod and grope,
To work, to ponder and to hope,
And meanwhile use the telescope
As we have done before.

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