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DEFINITIONS OF TERMS USED IN GEODETIC AND OTHER SURVEYS

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INTRODUCTION

Recognizing the need for authoritative definitions of surveying and mapping terms, the Federal Board of Surveys and Maps in 1938 appointed a special committee to prepare such definitions. Confronted with an apparent choice of making a complete examination of the terminology employed in the large and ever-widening fields of surveying and mapping or of limiting its attention to terms for which there appeared a current need of definition, the committee decided to do both: to gather for study and future action material relating to any terms in which the members of the Board might have even a slight interest, but to give priority in its discussions and determinations to those terms for which there appeared a present need of definition. In following this program, a number of definitions were completed and reported to the Board. At the same time there was gathered into the files of the chairman of the special committee considerable material, diverse in character and incomplete, relating to other terms which it was hoped would eventually come before the committee for study and action.

The Federal Board of Surveys and Maps was abolished in March 1942 by Executive Order (No. 9094), and its Committee on Definitions of Surveying and Mapping Terms thereby discharged. At that time, comparatively few definitions in geodesy and geodetic surveying had been completed, and it was to provide such definitions that the work which the Committee had previously been performing was continued under the direction of Captain H. W. Hemple, Chief of the Division of Geodesy, U. S. Coast and Geodetic Survey. This publication was prepared in that Division, with the major part of the work being done by Hugh C. Mitchell. After Mr. Mitchell's retirement, a few minor changes and additions were made to incorporate suggestions received after the submission of copies of the manuscript to various authorities and interested persons.

It will be noted that for each term presented there is a basic definition or description directly following the name of the term. This is intended to contain all the elements and only the elements which are essential to a complete and accurate definition or description. For many terms there are also supplementary statements (set off in separate paragraphs), designed to facilitate the interpretation of the basic definition and to call attention to other uses that may have been made of the terms defined. A few supplementary statements also contain information of historical character which is sometimes desired but not always easy to find. The object of the supplementary statements is to make the report generally more useful. *Terms defined under another heading are italicized.*

Included in the publication are definitions which had been completed by the Committee on Definitions of the Federal Board of Surveys and Maps before its dismissal. These are identified by an asterisk (*). They were not acted upon by the Board. Included also are terms which might appear to have little relation to geodetic surveying, but the great advances of recent years in the use of geodetic data for the control of other surveys make it desirable that the geodetic engineer be familiar with the language of those who may use the data which he determines.

A

aberration: annual.—See under *aberration of light (astronomy)*.

chromatic.—See under *aberration of light (optics)*.

diurnal.—See under *aberration of light (astronomy)*.

spherical.—See under *aberration of light (optics)*.

aberration of light (astronomy).—The apparent displacement in position of a heavenly body which is due to the progressive motion (velocity) of light combined with the motion of the earth itself.

Aberration of light due to the *rotation* of the earth on its axis is termed diurnal aberration; its effect is considered in first-order determinations of *astronomical azimuth* and *longitude*, but not of *latitude*. Aberration due to the *revolution* of the earth about the sun is termed annual aberration.

aberration of light (optics).—The failure of light from a point on an object, after passing through a lens, to converge to a point on the image.

In a single lens having spherical surfaces, *aberration* may be caused by differences in the *focal lengths* of the various parts of the lens: rays passing through the outer part of the lens come to a *focus* nearer the lens than do rays passing through its central part. This is termed spherical aberration and, being due to the faulty figure of the lens, is eliminated by correcting that figure. A lens so corrected is called an *aplanatic lens*. Aberration may also result from differences in the wave lengths of light of different colors: light of the shorter wave lengths (violet end of the spectrum) comes to a *focus* nearer the lens than light of the longer wave lengths (red end of the spectrum). This is termed chromatic aberration, and is practically eliminated over a moderate range of wave lengths by using a composite lens, called an *achromatic lens*, composed of parts having different *dispersive powers*. See *refraction: index of refraction*.

absolute unit.—See under *unit*.

acceleration.—Rate of change of speed.

In the *c. g. s. system* of physical measurements, acceleration is expressed in terms of centimeters per second per second. See *gal*.

accessories: corner (United States public-land surveys).*—Physical objects adjacent to *corners*, to which such *corners* are referred for their future identification or restoration.

Accessories include *bearing trees*, mounds, pits, ledges, rocks, and other natural features to which distances or directions, or both, from the *corner* or *monument* are known. Strictly speaking, such accessories are a part of the monument.

accidental error.—See under *error*.

accumulated discrepancy.—See under *discrepancy*.

accumulated divergence (leveling).—See under *divergence*.

accuracy.*—Degree of conformity with a *standard*.

Accuracy relates to the quality of a result, and is distinguished from *precision* which relates to the quality of the operation by which the result is obtained.

The standard of reference may be (1) an exact value, such as the sum of the three *angles* of a plane triangle is 180°; (2) a value of a conventional *unit* as defined by a physical representation thereof, such as the *international meter*, defined by the *International Prototype Meter* (bar) at the National Bureau of Standards; (3) a survey or map value determined by refined methods and deemed sufficiently near the ideal or true value to be held constant for the control of dependent operations, such as the *adjusted elevation* of a *permanent bench mark* or the *graticule* of a *map projection*. The accuracy attained by field surveys is the product of the instructions to be followed in the execution of the work and the *precision* with which those instructions are followed.

achromatic lens.—A lens which transmits light without separating it into component colors.

An achromatic lens transmits light with a negligible amount of *chromatic aberration*. This is accomplished by means of lens elements of glass having different *indices of refraction*, so proportioned that the *chromatic aberration* in one element is compensated by that in another. Lenses that are made achromatic are usually also made *aplanatic*, that is, free of *spherical aberration*.

achromatic telescope.—A telescope having an *achromatic lens* for its object glass.

adjusted angle.—See under *angle*.

adjusted elevation.—See under *elevation*.

adjusted position.—See under *position*.

adjusted value.—See under *value*.

adjustment (leveling).—The determination and application of *corrections* to orthometric differences of elevation or to *orthometric elevations*, to make the *elevations* of all *bench marks* consistent and independent of the *circuit closures*.

adjustment: angle method of adjustment (triangulation and traverse).—A method of *adjustment of observations* which determines *corrections* to *observed angles*.

The angle method of adjustment may be used where a chain of single triangles is to be adjusted. For an extensive *triangulation* figure with overlapping triangles, the *direction method of adjustment* is preferred.

adjustment: collimation.—See under *collimation adjustment*.

adjustment: direction method of adjustment (triangulation and traverse).—A method of *adjustment of observations* which determines *corrections* to observed directions.

In the direction method, each *angle* is considered as the difference between two *directions,* for each of which a separate *correction* is determined. The direction method is used in the adjustment of *triangulation* figures which are composed of overlapping triangles, but for some work, where the survey consists of a chain of single triangles, the *angle method of adjustment* may be preferred.

adjustment: local.—See under *adjustment: station adjustment.*

adjustment: station.—The satisfying of conditions existing among *angles* as measured at a survey station. Also called local adjustment.

In a station adjustment, two kinds of conditions may require consideration: the sum of a series of measured *angles* closing the *horizon* may not equal exactly 360°; the sum of several contiguous *angles* measured separately may not equal the sum angle measured as a single *angle.* The term *observed angles* may be applied to the measured *angles* after they have been corrected by station adjustment.

adjustment correction (leveling).—See under *correction.*

adjustment of observations.—The determination and application of *corrections* corresponding to *errors* affecting the observations, making the observations consistent among themselves, and coordinating and correlating the derived data.

The object of *adjustment* is to provide the best (most probable) values of results obtainable from a series of survey observations, and to coordinate and correlate those results within the survey itself and with previously existing basic data. This is accomplished by mathematical analysis, as by the use of the *method of least squares;* or mechanically by graphical methods such as employed in plane-table surveying. The mathematical adjustment involves the solution of certain *condition equations* or *observation equations,* such as *angle equations, side equations, length equations,* and *latitude, longitude,* and *azimuth equations.* See, also, *adjustment: station.*

aerial map.—See under *chart: aeronautical chart.*

aerial navigation map.—See under *chart: aeronautical chart.*

aeronautical chart.—See under *chart.*

aeronautics.*—The science and art of navigation through the atmosphere.

air navigation chart.—See under *chart: aeronautical chart.*

air navigation map.—See under *chart: aeronautical chart.*

Airy theory of isostasy.—See under *isostasy.*

Aitoff equal-area map projection.—See under *map projection.*

Albers conical equal-area map projection.—See under *map projection.*

alidade.—The part of a surveying instrument which consists of a sighting device, with index, and reading or recording accessories.

The alidade of a *theodolite* or surveyor's *transit* is the upper part of the instrument: the *telescope, micrometer microscopes,* or *verniers,* and accessories, mounted on what is called the "upper motion" of the instrument, and used in observing a direction or angle on the graduated circle, which is mounted on the "lower motion."

The alidade used in topographic surveying consists of a straight-edge ruler carrying a *telescope* or other sighting device, and used in recording a direction on the *plane-table* sheet, which corresponds to the graduated circle of the *theodolite.* If a *telescope* is used, the instrument is often termed a *telescopic alidade.*

The movable arm of a sextant is an alidade.

alidade: telescopic.—A usual designation for an instrument composed of a *telescope* mounted on a straight-edge ruler, and used with a *plane table* in *topographic surveying.* See *alidade.*

alignment (alinement).—The placing of points along a straight line. Also, the location of points with reference to a straight line, or to a system of straight lines.

The use of the term alignment in surveying should be limited to operations associated with straight lines.

alignment: curve of.—See under *curve of alignment.*

alignment correction, tape.—See under *tape.*

almucantar.—Any small circle on the *celestial sphere* parallel with the *horizon.* Also termed parallel of altitude and circle of equal altitude.

alt-azimuth instrument.—An instrument equipped with both horizontal and vertical graduated circles, for the simultaneous observation of horizontal and vertical directions or angles.

The alt-azimuth instrument derives its name from the combination of the terms *altitude* and *azimuth.* Many *theodolites* and engineer's and surveyor's *transits* are alt-azimuth instruments; the *vertical circle* (instrument) used by the Coast and Geodetic Survey has a small horizontal circle as well as a larger, more *precise vertical circle,* and may be considered an alt-azimuth instrument, but the term is little used for surveying and mapping instruments. Its use may properly be restricted to designating an instrument of the *theodolite* type constructed for use in astronomical work, and sometimes called an astronomical theodolite or the universal instrument.

altimeter.—An *aneroid barometer* used for determining *elevations.*

altitude.—The *vertical angle* between the plane of the *horizon* and the line to the object which is observed or defined.

In astronomy and surveying, the altitude is positive if the object is above the *horizon,* and negative if below it. In surveying, a positive altitude is also termed an angle of elevation; a negative altitude, an angle of depression. In astronomy, altitude is the *complement* of the *zenith distance.* In photogrammetric surveying, altitude applies to *elevation* above *datum* of points in space.

altitude: circle of equal.—See under *almucantar.*

altitude: parallel of.—See under *almucantar.*

amplitude of vibration (pendulum).—The *arc* passed over by a *pendulum* in executing one *vibration.*

In the present use of the *Mendenhall pendulum,* the amplitude of vibration is measured in millimeters. In mathematics (harmonic analysis), the amplitude is the semi-arc or distance out from the mean position.

aneroid barometer.—See under *barometer.*

angle (general).—That relationship of lines or surfaces which is measured by the amount of *rotation* necessary to make one coincide with or parallel to another. See, also, *angle: solid.*

An angle may be expressed as a difference in directions of lines which lie: (1) In a plane, giving a *plane angle.* (2) In a curved surface, giving a *spherical angle, a spheroidal angle,* etc. (3) In two planes, measuring the inclination of one plane to the other, giving a *dihedral angle.*

In each case the magnitude of the angle is reckoned in units derived from a complete circumference of a circle. There are several systems of such units, of which the following are the most commonly used:

a) The degree (°) is 1/360th part of a circumference, and is the unit of the sexagesimal system used in this country. The degree is divided into 60 minutes (60′), and the minute into 60 seconds (60″).

b) The hour (^{h}) is 1/24th part of a circumference, and is the unit used in the angular expression of time. The hour is related to the degree by the equation: $1^h = 15°$. The hour is divided into 60 minutes (60^m), and the minute into 60 seconds (60^s). [Note that in the sexagesimal system the symbols for minutes and seconds are (′) and (″), and in the time system the symbols for minutes and seconds are (^{m}) and (^{s}).] An angle expressed in --° --′ --″ is said to be in *arc* measure; expressed in --^{h} --^{m} --^{s}, in time measure.

c) The *grad* or *grade* (^{g}) is 1/400th part of a circumference, and is the unit of the centesimal system used in France. It is related to the degree by the equation: $100^g = 90°$. The *grad* is divided into 100 centesimal minutes (100‵); and a centesimal minute is divided into 100 centesimal seconds (100‶). While, as indicated above, the prime and double prime with reverse slant (‵, ‶) are used to designate centesimal minutes and seconds, the common forms of the prime and double prime (′, ″) are used by some authors for the same purpose.

d) The radian (^{r}) is the angle at the center of a circle subtended by an *arc* having exactly the same length as the radius of the circle. One *radian* equals 360° divided by 2π or 57.30° approximately. Its value in seconds of *arc* is 206,205″. It is used in astronomy and navigation.

e) The mil is 1/6400 part of a circumference; it subtends 0.98 (approximately 1) linear unit at a distance of 1000 such units. It is related to the degree by the equation: 1 mil = 0.05625°. It is used in military operations.

Sometimes, a particular angle may be defined by giving the length of chord which subtends the angle at a stated distance. Thus, the angle which 1 foot subtends at a distance of 39 miles is equal to 1″. This is often expressed by the following saying "A second is a foot at forty miles."

In surveying operations, an angle is classified in various ways, as follows:

1) According to the position or character of the surface in which it lies: *horizontal angle, vertical angle,* oblique angle, *spherical angle, spheroidal angle.*

2) According to the method by which it is obtained: *observed angle, concluded angle, adjusted angle.*

3) According to the function which it serves in the computation of the survey data: *distance angle, azimuth angle.*

4) According to the relative position it occupies in a geometric figure: *interior angle, exterior angle.*

angle: adjusted.—An *adjusted value* of an *angle.*

An adjusted angle may be derived from either an *observed angle* or from a *concluded angle.*

angle: azimuth (astronomy).—The *angle* less than 180° between the plane of the *celestial meridian* and the *vertical plane* containing the observed object, reckoned from the direction of the elevated pole.

In astronomic work, the azimuth angle is the *spherical angle* at the *zenith* in the *astronomical triangle,* pole-zenith-star. In geodetic work, it is the *horizontal angle* between the celestial pole and the observed terrestrial object.

angle: azimuth (surveying).—An *angle* in *triangulation* or in *traverse* through which the computation of *azimuth* is carried.

In a simple *traverse,* every *angle* may be an azimuth angle. Sometimes, in a *traverse,* to avoid carrying *azimuths* over very short lines, supplementary observations are made over comparatively long lines, the *angles* between which form azimuth angles.

In *triangulation,* certain *angles,* because of their size and position in the figure, are selected for use as azimuth angles, and enter into the formation of the *azimuth condition equation* (*azimuth equation*).

angle: complement of.—The difference between an *acute angle* and one right *angle* (90°).

angle: concluded.—An *interior angle* between adjacent sides of a closed figure, which is obtained by subtracting the sum of all the other *interior angles* of the figure from the theoretical value of the sum of all the *interior angles.*

The concluded angle is most frequently met with in triangulation, where it is obtained by subtracting the sum of two known *angles* of a triangle from 180° plus the *spherical excess* of the triangle.

angle: deflection.—A *horizontal angle* measured from the prolongation of the preceding line, right or left, to the following line.

angle: dihedral.—An *angle* between two planes.

A dihedral angle is measured in a plane perpendicular to the line of intersection of the planes forming the *angle,* and is acute, right, oblique, or straight according to the nature of the plane angle which represents it.

angle: direct.—See under *angle to right.*

angle: distance.—An *angle* in a triangle opposite a side used as a base in the solution of the triangle, or a side whose length is to be computed.

In a chain of single triangles, as the computation proceeds through the chain, two sides in each triangle are used: a known side and a side to be determined: the *angles* opposite these sides are the distance angles.

angle: explement of.—The difference between an *angle* and four right angles (360°).

angle: exterior.—The *angle* between any side of a polygon and adjacent side extended.

Exterior angle is also used to designate the outside *angles* formed by a line intersecting two parallel lines. It has likewise been used in surveying to designate the *explement* of an *angle.* This latter use is rare.

angle: horizontal.—An *angle* in a horizontal plane.

The directions may be to objects in the horizontal plane; or they may be the lines of intersection of the horizontal plane with the *vertical planes* containing the objects.

angle: interior.—An *angle* between adjacent sides of a closed figure, measured by the *arc* connecting those sides on the inside of the closed figure.

The three *angles* of a triangle are interior angles.

angle: observed.—An *angle* obtained by direct instrumental observation.

A measured *angle* which has been corrected for local conditions (see *adjustment: station*) only at the point of observation, is considered an observed angle.

angle: parallactic.—See under *astronomical triangle.*

angle: refraction.—See under *refraction angle.*

angle: solid.—The integrated angular spread at the vertex of a cone, pyramid, or other solid figure.

The unit of measure of a solid angle is the steradian, a solid angle at the center of a sphere which is subtended by a portion of the surface of the sphere having an area equal to the square of the radius of the sphere.

angle: spherical.—An *angle* between *great circles* on a sphere.

A spherical angle is measured either: a) by the *dihedral angle* of the planes of *great circles* or b) by the plane angle between tangents to *great circles* at their intersection.

angle: spheroidal.—An *angle* between two curves on a *spheroid,* measured by the *angle* between their tangents at the point of intersection.

angle: supplement of.—The difference between an *angle* and two right angles (180°).

angle: vertical.—An *angle* in a *vertical plane.*

In surveying, one of the directions which form a vertical angle is usually either (a) the direction of the *vertical* (*zenith*), and the *angle* is termed the *zenith distance;* or (b) the line of intersection of the *vertical plane* in which the *angle* lies with the plane of the *horizon,* and the *angle* is termed the *angle of elevation* or *angle of depression,* or simply the *altitude* (plus or minus, as the case may be). The vertical angle between two directions, neither of which lies in the plane of the *horizon* or coincides with the *vertical,* is usually obtained from the combination of two vertical angles as defined above.

angle equation.—See under *equation.*

angle method of adjustment (triangulation and traverse).—See under *adjustment.*

angle of depression.—See under *altitude.*

angle of elevation.—See under *altitude.*

angle of incidence.—See under *refraction of light.*

angle of inclination.—An *angle of elevation* or an *angle of depression.* See *altitude.*

angle of refraction.—See under *refraction of light.*

angle to right.—The *horizontal angle* measured clockwise from the preceding line to the following one.

angles: repetition of.—See under *repetition of angles.*

annual aberration.—See under *aberration of light* (*astronomy*).

annual parallax.—See under *parallax.*

anomalistic month.—See under *month.*

anomalistic year.—See under *year.*

anomaly (astronomy).—The *angle* at the sun between the radius vector of a planet and the *line of apsides* of its orbit, reckoned from *perihelion.*

The term defined above is also called the true anomaly, when it is desired to distinguish it from the eccentric anomaly, which is the corresponding angle at the center of the orbit; or from the mean anomaly, which is what the true anomaly would become if the planet had a uniform angular motion.

anomaly (general).—A deviation from a norm.

anomaly (geodesy).—A deviation of an observed value from a theoretical value, due to an abnormality in the observed quantity.

anomaly: Bouguer.—A difference between an observed value of *gravity* and a theoretical value at the point of observation, which has been corrected for the effect of *topography* only, the topography being considered as resting on a plane of indefinite extent.

In practice, a Bouguer *anomaly* is obtained through a series of approximations. First, the *topography* is treated as an indefinite slab of a thickness equal to the elevation of the station above *sea level,* the rate of change of *gravity* with elevation depending upon the assumed density of the slab, and being about five-eighths the normal value of that ratio. This first approximation gives the main part of the *anomaly.* The determination of the effect of this indefinite slab is the first step in the Hayford-Bullard (or Bullard) method of isostatic reduction.

Second, allowance is made for the departure of the actual *topography* from the indefinite slab. This correction is usually small. The distance out from the station for which it is computed is a matter of convenience; while no precise rule has been adopted for selecting this distance, it has been suggested that it should increase with elevation of station. The practice in the United States Coast and Geodetic Survey is to compute this second correction out to Zone O of the Hayford divisions of the surface of the earth, that is, 166.7 kilometers or about 100 miles out from the station. See *template* (*templet*).

A third approximation is sometimes made by taking account of the curvature of the sea-level surface. The numerical value of this correction is small, unless the computation is carried to a great distance from the station. In the work of the United States Coast and Geodetic Survey, no account is taken of this correction and, according to Helmert, it should not be used. However, reasons have been advanced favoring its inclusion in a complete computation of a Bouguer anomaly.

For use in reducing *gravity* observations to obtain even an approximate approach to a theoretical value, the Bouguer method has proved of little or no value. It ignores *isostatic compensation* and creates large fictitious *anomalies;* it neglects large amounts of matter existing between the *geoid* and the *spheroid;* and it takes no account of actual *topography* beyond the limited distance used in the computation of the second correction (above). It has, however, proved useful to oil companies in their geophysical investigations: if Bouguer anomalies are available at a number of stations within a limited area, values of this *anomaly* at other points within the area can be obtained by interpolation, and from these, serviceable values of *gravity* are obtained by computation.

The use of the pendulum in determining the figure of the earth came in at about the beginning of the nineteenth century, and with that use came the application of Bouguer's rule for the reduction of gravity observations. The method continued in favor until Clarke and Helmert, applying the theories of Pratt and Airy which are now known as the principle of *isostasy,* showed that it did not come anywhere near producing reliable values of theoretical gravity. Its present use is limited to theoretical studies and to the practical application given above.

The Bouguer anomaly derives its name from the French mathematician, Pierre Bouguer (1698–1758), who did not develop the method itself, but who proposed the rule or formula expressing the effect of a slab of indefinite extent, as considered in making the first approximation (above). In its time, the Bouguer rule has also borne the names of Young (Thomas Young, 1773–1829) and Poisson (Simon Denis Poisson, 1781–1840).

anomaly: deflection.—The difference between an uncorrected value of the *deflection of the vertical* as determined by observation and the value after being corrected in accordance with certain assumptions made with reference to the physical condition of the *geoid.*

The term deflection anomaly is seldom used. As it applies to the *residuals* obtained from solutions of equations set up in conformity with some adopted theory of distribution of mass in the outer part of the earth's crust, the term *residual* is more generally used, qualified, if need be, by a designation of the particular solution through which it was obtained.

anomaly: free-air.—The difference between observed gravity and theoretical gravity which has been computed for latitude and corrected for elevation of the station above the geoid, by application of the normal rate of change of gravity for change of elevation, as in free air.

The elevation correction is for height above the *geoid*, not the *spheroid*, the relation of which to the *geoid* is practically always unknown. No correction is applied for the effect of topography and isostatic compensation.

anomaly: gravity.—The difference between the observed value of gravity at a point and the theoretical value, in the sense, observed minus theoretical.

The theoretical value may be obtained in various ways. See *anomaly: free-air; anomaly: Bouguer; anomaly: isostatic*. The point at which the two values of gravity are compared is commonly either the point of observation or a point on the geoid directly under (or above) the point of observation.

The value of the gravity anomaly is the same for either point of comparison. However, in framing a definition, it is desirable to adopt one convention or the other. In the United States, since one of the purposes of the isostatic studies of the U. S. Coast and Geodetic Survey has been to explain observed gravity, the point of observation has been used as the point of comparison. Elsewhere, the almost universal practice has been to take the point on the *geoid* directly below (or above) the point of observation, even for isostatic studies, since the original use of gravity observations was to determine the *flattening of the earth:* this fact has determined the convention adopted for defining gravity anomaly.

If we knew the relation between the geoid and the spheroid of reference (a formula for theoretical gravity implies a spheroid of reference), we could reduce gravity to the spheroid of reference: this is often done in theoretical investigations.

When it is desired to explain the observed value of gravity by some theory, it is natural to take the point of observation as the point of comparison. If, on the other hand, it is desired to use observations of gravity to determine the figure of the earth, the natural point of comparison is the point on the geoid directly below (or above) the point of observation. For studies of this sort, it is necessary to reduce all observations to a common level surface.

anomaly: isostatic.—The difference between an observed value of *gravity* and a theoretical value at the point of observation which has been corrected for elevation of the station above the geoid and for the effect of *topography* over the whole earth and for its *isostatic compensation*.

The present procedure is to compute the *isostatic compensation* according to the *Pratt theory of isostasy* as developed by Hayford, using various depths for purposes of comparative analysis. Isostatic anomalies obtained by the above procedure are sometimes called Hayford gravity anomalies or, simply, Hayford anomalies. Other types of isostatic anomaly may be distinguished by the author's basic assumptions and designated by the author's name, as Meinesz anomaly, Heiskanen anomaly, etc.

Antarctic Circle.—The *geographic parallel* having a south *latitude* equal to the *complement* of the *declination* of the *winter solstice*.

The *obliquity of the ecliptic* is steadily changing, so that the *winter solstice* is not a point of fixed *declination*, and the Antarctic Circle as defined above is not a line of fixed position. When the Antarctic Circle is to be shown on a *map*, it is desirable that it be treated as a line of fixed position, and a conventional value adopted for its *latitude*. For this purpose, the value 66°33′ south *latitude* is here proposed. This is the *complement* of 23°27′, proposed for the *latitude* of the *Tropic of Capricorn*.

The area enclosed by the Antarctic Circle is called the "South Frigid Zone," and at all points in this area, at the time of the *winter solstice*, the sun is above the *horizon* at local midnight. The belt of the earth's surface bounded by the Antarctic Circle and the *Tropic of Capricorn* is called the "South Temperate Zone." See *Arctic Circle*.

aphelion.—The point in an elliptical orbit of a planet or comet remotest from the sun.

aplanatic lens.—A lens which transmits light without *spherical aberration*.

apparent (visible) horizon.—See under *horizon*.

apparent solar day.—See under *day*.

apparent solar time.—See under *time*.

apparent time.—See under *time*.

approximate.—Approaching closely but not attaining a specified *accuracy* or a *precision* conformable with the quality of the observations.

Too few observations or observations made with an inferior instrument will give an approximate result.

Omitted corrections or the neglect of terms having significant values will produce an approximate result, even where the observations themselves are satisfactory.

apsides: line of.—See under *line of apsides*.

arc (general).—A portion of a mathematically defined curve.

A circular arc is part of a circle; an elliptical arc, part of an ellipse; etc.

arc correction (pendulum).—The quantity which is applied to the period of *vibration* of a *pendulum* to allow for the *pendulum's* departure from simple harmonic motion.

With a *pendulum*, the *acceleration* is proportional to the sine of the *amplitude*, while the displacement is proportional to the *amplitude* itself. The *arc* is the quantity obtained by observation, and it is slowly changing; the *acceleration* is the quantity sought. By limiting the size of the *amplitude*, the correction required to take account of this non-isochronous condition is kept quite small.

arc triangulation.—See under *triangulation*.

Arctic Circle.—The *geographic parallel* having a north *latitude* equal to the *complement* of the *declination* of the *summer solstice*.

The *obliquity of the ecliptic* is steadily changing so that the *summer solstice* is not a point of fixed *declination*, and the Arctic Circle as defined above is not a line of fixed position. When the Arctic Circle is to be shown on a *map*, it is desirable that it be treated as a line of fixed position, and a conventional value adopted for its *latitude*. For this purpose, the value 66°33′ north latitude is here proposed. This is the *complement* of 23°27′, proposed for the *latitude* of the *Tropic of Cancer*.

The area enclosed by the Arctic Circle is called the "North Frigid Zone," and at all points in this area, at the time of the *summer solstice*, the sun is above the *horizon* at local midnight. The belt of the earth's surface bounded by the Arctic Circle and the *Tropic of Cancer* is called the "North Temperate Zone."

Actually, when an observer sees the sun at a *solstice* just touch the *horizon* at local midnight, without setting, he is probably much nearer to the 66th parallel of latitude than to the one proposed above for cartographic use. This is an effect of *atmospheric refraction.* It is modified by local conditions, including *dip of horizon.*

area triangulation.—See under *triangulation.*

arithmetical mean.—The value obtained by dividing the sum of a series of values by the number of values in the series. See *weighted mean.*

artificial horizon.—See under *horizon.*

A-stations (traverse).—*Subsidiary stations* established between *principal stations* of a *survey traverse,* for convenience of measuring, to obtain the distance between the *principal stations.*

A-stations are established along a route which is not straight, as along a curved section of a railroad, where the length measures must be carried through a series of short *straight lines,* while *azimuth* control may be carried through widely spaced *stations.* The A-stations form a traverse loop with the line connecting the *principal stations,* the distance between which is obtained by projecting the measured lengths of the short lines onto that main line. See *equation: perpendicular (traverse).* A-stations are so-called because in a given series, these stations are designated by the name of a *principal station* followed by the letters A, B, C, etc., in order of distance from the *principal station.* They are sometimes referred to as "A, B, C stations."

astrolabe.—An instrument for measuring *altitudes* of celestial objects. See under *astrolabe: pendulum astrolabe; planispheric astrolabe; prismatic astrolabe.*

Derived from Greek words meaning "to take a star," the term astrolabe has been used to designate a great variety of instruments, of which the three named above are of especial interest to surveyors and map makers.

astrolabe: pendulum.—An astronomical instrument using a constant altitude for position determination. Its distinctive feature is a mirror suspended on top of a pendulum to form the *artificial horizon.*

The instrument consists of a V-shaped casting carrying the objective and eyepiece lenses at the ends of the arms. The mirror, which rests on top of the pendulum and forms the level surface (artificial horizon), is located at the intersection of the V. The pendulum is suspended so that it is free to swing in either of two planes at right angles to each other, such as north-south and east-west planes. The pendulum is highly damped so that the mirror comes to rest quickly and remains steady under normal observing conditions.

astrolabe: planispheric.—An *astrolabe* of ancient origin, consisting of a full graduated circle with a centrally mounted *alidade,* and accessory adjustable plates on which are engraved *stereographic projections* of the heavens and of the sphere for local *latitudes.*

The instrument is held suspended in a *vertical plane,* the *altitude* of a star is observed with the aid of the *alidade,* and the projection-bearing plates are so adjusted that, with the data available, what are essentially graphical solutions of astronomical problems are effected.

astrolabe: prismatic.—An *astrolabe* consisting of a *telescope* in a horizontal position, with a prism and *artificial horizon* attached at its objective end, used for determining *astronomic positions.*

The usual form of this instrument employs a 60° prism, with the face nearest the objective perpendicular to the *line of collimation* of the *telescope;* a small mercurial horizon is attached to the instrument beneath the prism. In observing, two images of a star are seen: one reflected directly into the *telescope* by the lower face of the prism; the other reflected first by the mercurial horizon, then by the upper face of the prism into the *telescope.* These two images of the same star are moving in opposite directions, and at the instant of the coincidence, the star is at the apparent *altitude* of the prism angle. Prismatic astrolabes may be made with the angle between the two inclined at other than 60° An English instrument employs a 45° *angle,* and has accessory means of obtaining more than one observation for a given setting.

astronomic; astronomical.—Of or pertaining to astronomy, the science which treats of the heavenly bodies, and the art based on that science.

For particular usage of the two forms, astronomic, astronomical, see *-ic; -ical.*

astronomic azimuth.—See under *azimuth.*

astronomic azimuth mark.—See under *azimuth mark.*

astronomic coordinates.—See under *coordinates.*

astronomic equator.—See under *equator.*

astronomic latitude.—See under *latitude.*

astronomic longitude.—See under *longitude.*

astronomic meridian.—See under *meridian.*

astronomic parallel.—See under *parallel.*

astronomic position.—See under *latitude: astronomic; longitude: astronomic.*

astronomical day.—See under *day.*

astronomical leveling.—See under *leveling.*

astronomical refraction.—See under *refraction.*

astronomical theodolite.—See under *alt-azimuth instrument.*

astronomical time.—See under *time.*

astronomical transit.—See under *transit.*

astronomical traverse.—See under *traverse.*

astronomical triangle.—The triangle on the *celestial sphere* formed by *arcs* of *great circles* connecting the celestial pole, the *zenith,* and a celestial body.

The *angles* of the astronomical triangle are: at the pole, the *hour angle;* at the celestial body, the parallactic angle; at the *zenith,* the *azimuth angle.* The sides are: pole to *zenith,* the *co-latitude; zenith* to celestial body, the *zenith distance;* and celestial body to pole, the *polar distance.*

astronomical unit.—The mean distance of the earth from the sun; that is, the semi-major axis of the elliptical orbit described by the earth around the sun, equal to about 149,500,000 kilometers (Smithsonian Physical Tables, 1934).

While the above simple definition is generally used in technical and popular publications, mathematical astronomers find it convenient to adopt a highly technical definition involving the use of a constant (k^2) introduced by Gauss to define the *acceleration* of the sun's gravitational field, and in particular the exact value of k^2 used by Gauss, although the astronomical data used by him to determine it differ slightly from the best modern values.

The *solar parallax* is a measure of the astronomical unit, and in some astronomical calculations it is convenient to use the *solar parallax* in place of the astronomical unit.

asymmetry of object (target).—Lack of symmetry in the visible aspect of an object as seen from a particular point of observation.

A square or rectangular pole may so face the observer that the line bisecting its tangents does not pass through its geometrical center. With a square cupola or tower, the *error* resulting from observing tangents and taking a mean may be quite large. The *error* due to asymmetry of object observed on is of the same character and requires the same treatment as *error* due to observing on an *eccentric object*. Asymmetry and *phase* are closely associated, but are not identical.

atmospheric refraction.—See under *refraction.*

authalic (equal-area) latitude.—See under *latitude.*

autogonal map projection.—See under *map projection.*

autumnal equinox.—See under *equinox.*

auxiliary guide meridian (United States public-land surveys).—See under *meridian.*

auxiliary standard parallel (United States public-land surveys).—See under *parallel.*

average error.—See under *error.*

aviation chart.—See under *chart: aeronautical chart.*

aviation map.—See under *chart: aeronautical chart.*

axis of lens (lens axis).—See under *principal axis.*

axis of level; axis of level bubble.—See under *level axis: spirit level axis.*

azimuth (general).——The *horizontal direction* reckoned clockwise from the meridian plane. See specific definition for *azimuth: astronomic; azimuth: geodetic; azimuth: grid;* etc.

In the basic control surveys of this country, azimuths are measured clockwise from south following the continental European geodetic practice. However, this practice is not followed in all countries.

azimuth: astronomic.—At the point of observation, the *angle* measured from the *vertical plane* through the celestial pole to the vertical plane through the observed object.

Astronomic azimuth is the *azimuth* which results directly from observations on a celestial body: it is measured in the plane of the *horizon,* and is usually reckoned from south (0°), through west (90°), north (180°), and east (270°), back to south (360° or 0°). It is affected by the local *deflection of the vertical* (*station error*) which, in the United States, produces differences between astronomic and *geodetic azimuths* of as much as 26″ in the mountain regions of the west, and of 10″ in the less rugged eastern States.

Astronomic azimuths may also be reckoned clockwise from north through 360°. In navigation, they are sometimes reckoned clockwise or counter-clockwise through 180°, from the south in the southern hemisphere, and from the north in the northern hemisphere. In recording an astronomic azimuth it is essential that both the initial and the direction of reckoning be indicated.

azimuth: back.—See under *azimuth: geodetic.*

azimuth: direction method, determination of astronomic azimuth.—The determination of the *astronomic azimuth* of a line by measuring with a *direction theodolite* the *horizontal angle* between a selected star and a suitable mark, and applying that *angle* to the *azimuth* of the star computed for the epoch of the observation.

In the horizontal *control surveys* of continental United States, the direction method of azimuth determination is preferred over other methods. A circumpolar star is observed at any *hour angle,* the mark being a signal light on a *main-scheme station* or at a station, called an *azimuth mark,* established for the purpose. A *correction for inclination of the horizontal axis,* depending upon the *altitudes* of the star and of the mark, is applied to the observed *angle,* and *curvature correction* and *corrections* for *variation of the pole* and for *diurnal aberration* also enter into the computation.

azimuth: forward.—See under *azimuth: geodetic.*

azimuth: geodetic.—For the *geodesic line* from A to B, the angle between the tangent to the *meridian* at A and the tangent to the geodesic line at A. In the U. S. Coast and Geodetic Survey, this angle is measured clockwise from south, but see under *azimuth (general).*

This azimuth is called the forward azimuth for the line AB. The angle between the tangents to the meridian and to the geodetic line at B is called the back azimuth for the line AB. Because of the *convergence of the meridians,* the forward and backward azimuths of a line do not differ by exactly 180°, except where the two end points have the same *geodetic longitude* or where the *geodetic latitudes* of both points are 0°.

The geodesic line is not, except in special cases, a plane curve, but for short lines (of the length commonly used in triangulation) one may neglect the small difference between the geodesic line and the plane curve actually observed.

azimuth: grid.—The *angle* in the plane of projection between a straight line and the central meridian (axis of *Y*) of a *plane-rectangular coordinate system.*

In the *State plane-coordinate systems* established by the U. S. Coast and Geodetic Survey, grid azimuths are reckoned from south (0°) clockwise through 360°. While essentially a *map* quantity, a grid azimuth may, by mathematical process, be transformed into a *survey* or ground quantity. See *gisement.*

azimuth: Laplace.—A *geodetic azimuth* derived from an *astronomic azimuth* by means of the *Laplace equation.*

It is proposed that the symbol α_L be adopted to designate a Laplace azimuth, to distinguish it from a *geodetic azimuth* derived by computation through the triangulation, which is represented by the symbol α_G.

See *Laplace equation.*

azimuth: magnetic.—At the point of observation, the *angle* between the *vertical plane* through the observed object and the *vertical plane* in which a freely suspended symmetrically magnetized needle, influenced by no transient artificial magnetic disturbance, will come to rest.

Magnetic azimuth is generally reckoned from magnetic north (0°) clockwise through 360°. Such an *azimuth* should be marked as being magnetic, and the date of its applicability be given.

azimuth: method of repetitions, determinations of astronomic azimuth.—The determination of the *astronomic azimuth* of a line by accumulating on the horizontal circle of a *repeating theodolite* the sum of a series of measures of the *horizontal angle* between a selected star and a suitable mark, and applying the mean of such measures to the *azimuth* of the star computed for the mean epoch of the observations.

The method of repetitions for the determination of *azimuth* is theoretically susceptible of great *accuracy* and *precision,* but in practice is not as satisfactory as the *direction method.*

A *correction for inclination of the horizontal axis,* depending on the *altitudes* of the star and of the mark, is applied to the observed *angle,* and *curvature correction* and *corrections* for *variation of the pole* and for *diurnal aberration* also enter into the computations.

azimuth: micrometer method, determination of astronomic azimuth.—The determination of the *astronomic azimuth* of a line by measuring indirectly with an *ocu-*

lar micrometer attached to a *theodolite* or *transit* the *horizontal angle* between a selected star at its elongation and a suitable ground mark (light) placed close to the *vertical plane* which passes through the star, and applying that *angle* to the *azimuth* of the star computed for the epoch of the observation.

At elongation, the apparent motion in *azimuth* of a close circumpolar star like Polaris is very small for an appreciable period of time, and a series of observations can be made by the micrometer method without reorienting the instrument. A *correction for inclination of the horizontal axis,* depending on the *altitudes* of the star and of the mark, is applied to the *observed angle,* and *curvature correction* and corrections for *variation of the pole* and for *diurnal aberration* also enter into the computations. Recently, difficulties in determining *astronomic azimuth* in Alaska, due to the large *altitude* of circumpolar stars, were overcome by employing the micrometer method with a *Bamberg broken-telescope transit.*

azimuth: normal section.—For the *normal section line* from A to B, the *angle* at A between the meridian plane and the normal section which passes through B.

azimuth angle (astronomy).—See under *angle.*

azimuth angle (surveying).—See under *angle.*

azimuth equation.—See under *equation.*

azimuth line.—See under *azimuth plane.*

azimuth mark: astronomic.—A signal or target whose *astronomic azimuth* from a survey station is determined from direct observations on a celestial body.

The mark may be a lamp or illuminated target placed especially for the purpose; or it may be a signal lamp at another survey station.

azimuth mark: geodetic.—A marked point established in connection with a *triangulation* (or *traverse*) *station* to provide a starting *azimuth* for dependent surveys.

The *geodetic azimuth* from the station to the azimuth mark is determined instrumentally; its distance is often determined only approximately, but should be sufficiently great to render negligible the angular effect of the ordinary *errors* of centering instrument and target. Since 1928, azimuth marks consisting of bronze tablets set in concrete or stone have been established in connection with the basic horizontal *control survey* of the United States. These marks are usually so located as to be readily available without special construction to elevate either instrument or target. At a station having an established azimuth mark, both the *geodetic azimuth* and the *grid azimuth* of the mark on the *State coordinate system* are computed and published.

azimuth mark: Laplace.—An *astronomic azimuth mark* at a *Laplace station.*

azimuth plane.—Any *vertical plane.*

Such a plane cuts an azimuth section from the *spheroid,* and traces an azimuth line on its surface. These terms are rarely seen and their use should be avoided. *Although* the *vertical planes* containing the prime vertical and the *meridian* are sometimes regarded as not being azimuth planes, they are special cases of that term as here defined.

azimuth section.—See under *azimuth plane.*

azimuthal (zenithal) map projection.—See under *map projection.*

azimuthal equidistant map projection.—See under *map projection.*

B

Bache-Wurdeman base-line measuring apparatus.—See under *base apparatus.*

back azimuth.—See under *azimuth: geodetic.*

backsight (general).—A sight on a previously established survey point.

backsight (leveling).—A reading on a rod held on a point whose *elevation* has been previously determined, and which is not the closing sight of a level circuit.

In leveling, a *backsight* is sometimes called a plus sight, because it is usually added to the *elevation* of the rod point to obtain the height of the instrument (H. I.). This is not always the case: the pointing may be on a mark on a wall or in the roof of a mine tunnel, with the instrument at a lower *elevation.* In such a case, the *backsight* will be subtracted from the known *elevation* to obtain the height of instrument. The term *backsight* is preferred over plus sight.

backsight (transit traverse).—A sight on a previously established survey point, which is not the closing sight of the *traverse.*

balancing a survey.—Distributing *corrections* through a *traverse,* to eliminate the *errors of closure.*

Errors of closure may arise when a *traverse* closes upon itself or when it extends between points of known *position. Corrections* to balance the *closing errors* are distributed through the *traverse* according to some approved method, so that the resulting survey figure will be geometrically consistent: the *position* and *azimuth* at the closing point as derived by computation carried through the balanced *traverse* will agree with the starting data for a *closed traverse* or with the fixed data where the *traverse* extends between fixed points. For an extended *traverse,* the elimination of errors may be made by the *method of least squares,* and the operation is termed an *adjustment.* For local work, the elimination of *errors* may be made by one of two standard methods, and is termed balancing the survey. These methods are termed *compass rule* and *transit rule.*

balancing a survey, compass rule.—*Corrections* corresponding to the *closing errors* in *latitude* and *departure* are distributed according to the proportion: length of line to total length of *traverse.*

The compass rule is used when it is assumed that the *closing errors* are as much due to *errors* in *observed angles* as to *errors* in measured distances.

balancing a survey, transit rule.—*Corrections* corresponding to the *closing errors* in *latitude* and *departure* are distributed according to the proportion: *latitude* and *departure* of each line of the *traverse* to the arithmetical sums of the *latitudes* and *departures* of the entire *traverse.*

The transit rule is used when it is assumed that the *closing errors* are due less to the *errors* in the *observed angles* than to *errors* in the measured distances.

Bamberg broken-telescope transit.—See under *transit: broken-telescope.*

bank of stream.—The continuous margin along a river where all vegetation ceases.

The right bank of a stream is the bank on the right-hand side, and the left bank, the one on the left-hand side, as one proceeds in the direction in which the current flows (downstream).

Barlow leveling rod.—See under *leveling rod.*

barometer.—An instrument for measuring atmospheric pressure.

There are two general types of barometers: those in which atmospheric pressure is balanced by the weight of a column of liquid (usually mercury); and those in which atmospheric pressure is balanced by some elastic device. The latter are termed *aneroid* (without liquid) *barometers.* A third kind of device for measuring atmospheric pressure is the *hypsometer,* which is not classed as a barometer.

barometer: aneroid.—A *barometer* which balances the atmospheric pressure against a mechanically elastic device.

The usual form of aneroid barometer consists of a thin box of corrugated metal, almost exhausted of air. When the atmospheric pressure increases, the box contracts; when the pressure lessens, the box expands. By mechanical means these movements are amplified and communicated to an index hand which registers on a graduated dial. The *graduations* on the dial are usually such as will show the atmospheric pressure in terms of height of a corresponding column of mercury. The aneroid barometer may be equipped with an auxiliary dial, graduated to show *elevations* in feet corresponding to atmospheric pressure.

barometer: cistern.—A *mercury barometer* in which a column of mercury is enclosed in a vertical glass tube, the upper end of which is sealed and exhausted of air, and the lower end placed in a cistern or reservoir of mercury which is exposed to atmospheric pressure.

The amount of the atmospheric pressure on the free surface of the mercury in the cistern determines the height to which the mercury will rise in the vertical tube. This may be measured, and the pressure reported in terms of that height, as so many *inches* of mercury.

barometer: mercury.—A *barometer* in which atmospheric pressure is balanced against the weight of a column of mercury.

There are two types of mercury barometers, differing in the form of apparatus used, but not in the underlying principle. See *barometer: cistern; barometer: siphon.*

barometer: mountain.—A *barometer* constructed for use in leveling operations.

Mountain barometer is a general term, little used, for a *barometer* of any type which is constructed for safe transportation under difficult field conditions, so that it may be used in survey work. See *barometer: aneroid, altimeter.*

barometer: siphon.—A *mercury barometer* consisting of a column of mercury in a glass tube which is so bent as to have two vertical branches, one about one-fourth the length of the other. The end of the longer branch is closed and the air in it is displaced by the mercury, but the shorter branch is left open and the mercury thereby subjected to atmospheric pressure.

The difference of the height of the mercury in the two branches is a measure of the atmospheric pressure.

barometric hypsometry.—See under *hypsometry.*

barometric leveling.—See under *leveling.*

base apparatus (geodetic surveying).—Any apparatus designed for use in measuring with *accuracy* and *precision* the length of a *base line* in *triangulation,* or the length of a line in *first-* or *second-order traverse.*

Various kinds of apparatus have been designed for use in measuring *base lines,* including the following general types:

(1) Apparatus having a length unit composed of simple bars or tubes of wood, metal, or other material, suitably constructed for making *alignment,* contact, and temperature determination. The earliest bars used in *geodetic* work were of wood. The most effective apparatus of this type is the *iced-bar.*

(2) Apparatus consisting of bars or tubes of different metals having unequal *coefficients of thermal expansion,* so arranged that (a) the temperature effects on the lengths of the component parts are largely neutralized and the effective length of the apparatus remains almost constant, or (b) the component parts form a metallic thermometer, by means of which the temperature of the apparatus is obtained and its effect on the length of the apparatus determined.

(3) Apparatus consisting of tapes or wires of metal, usually steel or a nickel-steel alloy. Because of its large *coefficient of thermal expansion,* steel tapes can be used in *precision* measures of *base lines* only under favorable temperature conditions. In this country, they have been replaced almost entirely by tapes of nickel-steel (*invar* or nilvar), having very small *coefficients of thermal expansion,* and capable of giving good results through a wide range of temperature. While tapes or bands are used in this country, wires have been used in base-line operations in Mexico and in Europe.

base apparatus: Bache-Wurdeman base-line measuring apparatus.—A *compensating base-line measuring apparatus* having a measuring element composed of a bar of iron and a bar of brass, each a little less than 6 meters in length, held together firmly at one end, with the free ends so connected by a compensating lever as to form a *compensating apparatus.*

Described in Appendix No. 25, U. S. Coast and Geodetic Survey Report for 1854; description reprinted in Appendix No. 12, U. S. Coast and Geodetic Survey Report for 1873.

base apparatus: compensating base-line measuring apparatus.—A *base apparatus* having a length element composed of two metals having different *coefficients of thermal expansion,* so arranged and connected that the differential expansion of its components will maintain a constant length of the element, under all temperature conditions of use.

base apparatus: contact base-line measuring apparatus.—A *base apparatus* composed of bars whose lengths are defined by the distance between their end faces or points.

In use, the bars are laid end to end, one bar being kept in position while another bar is being moved ahead. There are various mechanical refinements connected with the moving of the bars into position, bringing the end of the new bar into contact with the end of the bar which is already in position without disturbing it.

base apparatus: contact-slide base-line measuring apparatus.—A modified *contact base-line measuring apparatus* consisting of two steel measuring bars (rods), each 4 meters in length, so mounted that contact is effected by coincidence of lines on a rod and a contact-slide. Each rod forms a metallic thermometer with two zinc tubes, one on each side of the bar: opposite ends of the bar are fastened to the ends of the tubes, the other ends of which are free to move with changes of temperature. Described in Appendix 17, U. S. Coast and Geodetic Survey Report for 1880.

base apparatus: duplex base-line measuring apparatus.—A *contact base-line measuring apparatus,* composed of two disconnected bars, one of brass and the other of steel, each 5 meters in length and so arranged as to indicate the accumulated difference of length of the measures from the brass and steel components.

The duplex base apparatus was designed by Wm. Eimbeck of the U. S. Coast and Geodetic Survey. It is described in Appendix No. 11, U. S. Coast and Geodetic Survey Report for 1897.

base apparatus: Hassler base-line measuring apparatus.—An *optical base-line measuring apparatus* consisting of four rectangular iron bars mounted end to end in a wooden box. Each bar is 2 meters long, the combined length of the apparatus being 8 meters.

Described in Transactions of the American Philosophical Society of Philadelphia, Pennsylvania, new series, 1825, Vol. II, pages 1273–1286. See also Appendix No. 21, U. S. Coast and Geodetic Survey Report for 1865.

base apparatus: iced-bar apparatus.—An apparatus for measuring linear distances with great *precision* and *accuracy,* and consisting essentially of a steel bar which is maintained at a constant temperature by being surrounded with melting ice.

The iced-bar apparatus is also called the Woodward base apparatus, after its designer, Dr. R. S. Woodward (1849–1924), of the U. S. Lake Survey. The bar is rectangular in cross-section, and is carried in a Y-shaped trough which is filled with melting ice and mounted on a car which moves on a track. Bar lengths are observed with *micrometer microscopes,* mounted on stable supports. The iced-bar apparatus is used in the laboratory in standardizing tapes, and it has also had some use in establishing *field comparators.*

base apparatus: optical base-line measuring apparatus.—A *base apparatus* composed of bars whose lengths are defined by distances between lines at or near their ends, which are observed by suitably mounted and adjusted microscopes.

In using any optical base-line measuring apparatus, the positions of the bars are controlled by microscopes on stable supports, whose *reticle* lines may be brought into coincidence with the *fiducial marks* on the bars, either by adjusting a bar or a microscope.

base apparatus: Repsold base-line measuring apparatus.—An *optical base-line measuring apparatus,* composed of a steel bar approximately 4 meters long, whose exact length at any temperature is known, and whose temperature is determined by means of a metallic thermometer composed of the steel measuring bar and a similar bar of zinc, the two being fastened together at their middle points. Described in Professional Paper No. 24, Engineering Corps, United States Army.

base apparatus: Schott base-line measuring apparatus.—A *contact, compensating base-line measuring apparatus* composed of three parallel bars, the middle bar of zinc, the outer bars of steel. One end of each steel bar is free; the other end is fastened to an end of the zinc bar, a different end for each steel bar. The lengths of the bars are so proportioned with respect to their *coefficients of thermal expansion* that a constant distance is maintained between the free ends of the steel bars. Described in Appendix No. 7, U. S. Coast and Geodetic Survey Report for 1882.

base apparatus: Woodward base-line measuring apparatus.—See under *base apparatus: iced-bar apparatus.*

base line (general).—A surveyed line established with more than usual care, to which surveys are referred for *coordination* and *correlation.*

Base lines are established for specific purposes, the more important ones, defined elsewhere, being as follows: *base line (triangulation)*; base line (echo sounding); *base line (United States public-land surveys)*; *base line (construction).*

base line (United States public-land surveys).*—A line extending east and west along the *astronomic parallel* passing through the *initial point,* along which *standard township, section,* and *quarter-section corners* are established.

As may be inferred from its designation, the *base line* is the line from which is initiated the survey of the meridional *township* boundaries and *section* lines. Auxiliary governing lines, known as *standard parallels* or *correction lines,* are established along the *astronomic parallel* usually at intervals of 24 miles north or south of the *base line.* In some of the very early surveys the base line is referred to as the "basis parallel."

base line: construction.—The center line of location of a railway or highway; often termed the "base line of location." A reference line for the construction of a bridge or other structure.

base line: triangulation.—The side of one of a series of connected triangles, the length of which is measured with prescribed *accuracy* and *precision,* and from which the lengths of the other triangle sides are obtained by computation.

Base lines in *triangulation* are classified according to the character of the work they are intended to control, and the instruments and methods used in their measurement are such that prescribed *probable errors* for each class are not exceeded. These *probable errors,* expressed in terms of the lengths, are as follows: first-order base line, 1/1,000,000; second-order base line, 1/500,000; third-order base line, 1/250,000.

base map.—See under *map.*

base tape.—A tape or band of metal or alloy, so designed and graduated and of such excellent workmanship that it is suitable for measuring the lengths of lines (*base lines*) for controlling *triangulation,* and for measuring the lengths of *first-* and *second-order traverse* lines.

In use, a base tape is subject to certain physical conditions which influence its effective length, and which must be taken into account in computing the length of a measured *base line.* These conditions include tension, temperature, method of support, sag, *grade, alignment,* and *standardization* length. See *tape corrections.* At one time, base tapes were made of steel, a metal having a high *coefficient of thermal expansion.* They are now made of *invar,* nilvar, or some other alloy having a very small *coefficient of thermal expansion.* See *invar.*

basic control.—See under *control.*

bathygraphic.*—Descriptive of ocean depths.

bathymeter.*—An instrument used for determining ocean depths.

Any deep-sea sounding apparatus. There are a number of designs of such instruments.

bathymetric.*—Relating to the measurement of ocean depths.

bathymetric chart.—See under *chart.*

bathymetry.*—The art or science of determining ocean depths.

bearing: grid.—The *angle* in the plane of the projection between a line and a north-south grid line.

bearing: true.—The *horizontal angle* between the *meridian line* and a line on the earth.

The term true bearing is used in many of the early descriptions of land boundaries in this country. It is associated with true north, referring to the direction of the north point as determined by astronomical observations. For future use, if an astronomically determined bearing is used, the term astronomic bearing is preferred over true bearing.

bearing of line (plane surveying).—The *horizontal angle* which a line makes with the *meridian* of reference adjacent to the quadrant in which the line lies. Bearings are classified according to the *meridian* used as *true bearings*, magnetic bearings, *grid bearings*.

A bearing is identified by naming the end of the *meridian* (north or south) from which it is reckoned and the direction (east or west) of that reckoning. Thus, a line in the northeast quadrant making an angle of 50° with the *meridian* will have a bearing of N. 50° E. In most survey work, it is preferable to use *azimuths* rather than *bearings*.

bearing tree (United States public-land surveys).*—A tree forming a *corner accessory*, its distance and direction from the *corner* being known.

Bearing trees are identified by prescribed marks cut into their trunks; the species and sizes of the trees are also recorded.

bed (mining).—A stratum in the earth's crust which has been formed in an approximately horizontal layer. If of rock, it is termed *bedrock*.

bed of stream.—The area within the *high-water lines* of a stream or river.

It is the area which is kept practically bare of vegetation by the wash of the waters of the stream from year to year.

bedrock.—A stratum of rock in the earth's crust which has been formed in an approximately horizontal position.

Large, deeply embedded *boulders*, with upper surfaces planed and leveled through exposure, are sometimes erroneously reported as bedrock in descriptive writing.

bench mark.—A relatively permanent material object, natural or artificial, bearing a marked point whose *elevation* above or below an adopted *datum* is known.

Usually designated as a B. M., such a mark is sometimes further qualified as a P. B. M. (*permanent bench mark*) to distinguish it from a T. B. M. (temporary bench mark), or *supplementary bench mark*, a mark of less permanent character intended to serve for only a comparatively short period of time.

bench mark: first-order.—A bench mark connected to the *datum* (usually mean sea level) by continuous *first-order leveling*.

bench mark: junction.—A *bench mark* selected as the common meeting point for *lines of levels* or *links of levels*.

bench mark: permanent.—A *bench mark* of as nearly permanent character as it is practicable to establish.

Usually designated simply as a *bench mark* or B. M., a permanent bench mark is intended to maintain its *elevation* with reference to an adopted *datum* without change over a long period of time. Concrete or stone posts, with suitable marks in their tops, such as inscribed disks, are used. Such a mark is set in firm ground, deep enough to be free from frost action, and in a location where disturbing influences are believed to be negligible.

bench mark: second-order.—A bench mark connected to the *datum* (usually mean sea level) by continuous *second-order leveling* or by a continuous combination of *first-order leveling* and *second-order leveling*.

bench mark: supplementary.—A *bench mark* at a junction of sections of a line of levels, at which no *permanent bench mark* is established.

A supplementary bench mark may be classed as a *temporary bench mark*, established to hold the end of a completed section of a line of levels and serve as an initial from which the next section is run. Spikes and screws in poles, bolts on bridges, and chisel marks on masonry are used for the purpose and may last for years.

bench mark: tidal.—A *bench mark* set to reference a tide staff at a tidal station and the elevation of which is determined with relation to the local *tidal datum*.

Bilby steel tower.—A *triangulation tower* consisting of two steel tripods, one within the other, designed by J. S. Bilby of the U. S. Coast and Geodetic Survey.

The Bilby steel tower was put into use in 1927 and is standard equipment in triangulation executed by the U. S. Coast and Geodetic Survey. The Bilby steel tower is demountable; it is easily erected, and as easily taken down and moved to a new location. Some of these towers have each been used at more than one hundred different stations.

blaze (United States public-land surveys).*—A mark made upon a tree trunk at about breast height, in which a flat scar is left upon the tree surface.

blunder.—A mistake.

A blunder is not an *error*, though a small blunder may remain undetected in a series of observations and have the effect of an *error* in determining a result. Examples of blunders are: reading a horizontal circle wrong by an even degree; neglecting to record a tape length in a measured *traverse*; reversing the numerals in recording an observation; etc.

Bonne map projection.—See under *map projection*.

Borda scale.—A *metallic thermometer* composed of two metals having different *coefficients of thermal expansion*.

The Borda scale was devised by the French scientist, Jean Charles Borda (1733–1799), who placed a strip of copper on a strip of platinum, fastened the two together at one end, and by measuring the relative movement of their free ends, determined their temperature. He used this means for determining the temperature of bars used in measuring the length of a geodetic *base line*. Later, Bessel used a combination of zinc and iron for the same purpose.

Boston leveling rod.—See under *leveling rod*.

Bouguer anomaly.—See under *anomaly*.

boulder.—A large rounded rock which has been separated from the mass of which it was originally a part.

Deeply embedded boulders may show an exposed surface which through weathering has the appearance of *bedrock*.

boundary: land.—A line of demarcation between adjoining parcels of land.

The parcels of land may be of the same or of different ownership, but distinguished at some time in the history of their descent by separate legal descriptions. A land boundary may be marked on the ground by material monuments placed primarily for the purpose; by fences, hedges, ditches, roads, and other service structures along the line; or defined by astronomically described points and lines; by *coordinates* on a survey system whose position on the ground is witnessed by material monuments which are established without reference to the boundary line; and by various other methods.

boundary line.—A line along which two areas meet.

In specific cases, the word "boundary" is sometimes omitted, as in "State line"; and sometimes the word "line" is omitted, as in "International boundary," "county boundary," etc. The term "boundary line" is usually applied to boundaries between political territories, as "State boundary line," between two States. A boundary line between privately owned parcels of land is termed a *property line* by preference, or if a line of the U. S. public-land surveys, is given the particular designation of that survey system, as *section line, township line,* etc.

boundary map.—A *map* constructed for the purpose of delineating a *boundary line* and adjacent territory.

boundary monument.—A material object placed on or near a *boundary line* to preserve and identify the location of the *boundary line* on the ground.

Where it is impracticable to establish a *monument* on or very close to a *boundary line,* the position of the *boundary line* on the ground is preserved by means of *reference marks.* The term *monument* is sometimes used to include both the mark on the *boundary line* and the *reference mark.* See also *monument (U. S. public-land surveys).*

boundary survey.—A survey made to establish or to reestablish a *boundary line* on the ground, or to obtain data for constructing a *map* or *plat* showing a *boundary line.*

The term boundary survey is usually restricted to surveys of *boundary lines* between political territories. For the survey of a *boundary line* between privately owned parcels of land, the term *land survey* is preferred, except that in surveys of the *public lands* of the United States, *cadastral survey* is used.

boundary vista.—A lane cleared along a *boundary line* passing through a wooded area.

A boundary vista is used for readily identifying a *boundary line,* and aiding in civil administration relating thereto.

Bowie effect (gravity).—The indirect effect on *gravity* due to the warping of the *geoid,* or the elevation of the *geoid* with respect to the *spheroid* of reference.

Also known as the Bruns term, the Bowie effect was discussed by Stokes, Bruns, Clarke, Helmert, and others, but it was under the direction of Bowie that a practical means was provided for computing its value for a given station. The *correction* for the Bowie effect is applied to the theoretical value of gravity, with the sign reversed. Values of the Bowie effect are tabulated in the *fundamental tables: deformation of the geoid and its effect on gravity.* The symbol $\Delta_2 g$ has been used to represent the Bowie effect.

Bowie Method (of adjustment).—A method devised in the U. S. Coast and Geodetic Survey under the direction of William Bowie for the *adjustment* of large networks of *triangulation.*

A description of the method is given in Special Publication No. 159, The Bowie Method of Triangulation Adjustment.

break-circuit chronometer.—See under *chronometer.*

broken grade (tape).—The change in *grade* when the middle point of a tape is not on *grade* with its ends.

If the middle support for the tape is not on the same *grade* as the end supports, the fact is noted with a reference "broken grade at —," naming the particular tape length which contains the broken grade.

broken-telescope transit.—See under *transit.*

bronze pendulum.—See under *pendulum.*

Brown gravity apparatus.—An apparatus for measuring the *acceleration of gravity* which utilizes the *Mendenhall pendulum,* but has a clamping device for holding the *pendulum* in the *receiver* when being transported from *station* to *station,* and which utilizes an electrical pick-up and amplifying device for recording the *oscillations (pendulum)* on the *chronograph* sheet.

The clamping device makes it unnecessary to remove the *pendulum* from the *receiver,* and thus avoids the necessity of breaking the vacuum seal each time a move is made. The recording of the *pendulum oscillations* on the *chronograph sheet* permits a direct time comparison of those *oscillations* with the radio time signals. One improvement of the Brown gravity apparatus over the *Mendenhall gravity apparatus* relates to the supporting of the *receiver* by leveling screws placed near the top of the *receiver,* making the *flexure (pendulum support)* less than in the earlier type of apparatus which had the leveling screws at the bottom of the *receiver,* and thus much further from the point of support of the *pendulum.*

Another improvement was the use of a cast aluminum chamber in which the *receiver* was hung as indicated above, and which was set directly in a mass of plaster of Paris placed at the bottom of a hole dug in the ground, and constituted a satisfactory stable support which was made ready more quickly than a concrete pier.

A third improvement over the old order consisted of the permanent installation in trucks of a greater portion of the electric wiring and auxiliary equipment. These improvements considerably reduced the time required by the earlier methods and apparatus for the determination of the *acceleration of gravity.* It was named for its designer, E. J. Brown of the U. S. Coast and Geodetic Survey, and was first used in the field in 1932.

bubble sextant.—See under *sextant.*

Bullard method of isostatic reduction.—See under *Hayford-Bullard (or Bullard) method of isostatic reduction.*

bulls-eye level.—See under *level: circular.*

bus and truck map.—See under *map.*

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cadastral control (United States public-land surveys).—Lines established and marked on the ground by suitable *monuments,* which are used as starting and closing points in surveys of the *public domain of the United States.*

The fundamental control of the public-land surveys of the United States consists of *base lines, standard parallels (correction lines), principal meridians,* and *guide meridians.*

cadastral map.—See under *map.*

cadastral survey.—See under *survey.*

Calendar: Gregorian.—The calendar established by Pope Gregory XIII in 1542 A. D., to correct the *Julian Calendar* by introducing the more *precise* value of the length of the *tropical year,* 365 days 5 hours 48 minutes 46.0 seconds *mean solar time.*

The Gregorian Calendar modified the requirement of the *Julian Calendar* that every fourth year be given an additional day by providing that, for centurial years, this would be done only where such years were divisible by 400. The calendar was brought into harmony with the seasons as they were at the time of the Council of Nice (A. D. 325) by dropping 10 days at the time of its becoming effective; October 4, 1582, being followed immediately by October 15. See *Calendar: Julian; double dating.*

Calendar: Julian.—The calendar devised by Julius Caesar in 45 B. C., and based upon the assumption that the true length of the *tropical year* was exactly 365¼ *mean solar days.*

The Julian Calendar provided that the ¼ day be absorbed by giving every fourth year one additional day; it made the *year* begin on January 1, a provision that was not universally followed even where other provisions of the calendar were followed; it was effective for the year 44 B. C., which was known as the "Year of Confusion" because, in order to bring the calendar into harmony with the seasons, two additional months were intercalated between November and December, giving it 14 months with a total of 445 days. See *Calendar: Gregorian; double dating.*

calendar month.—See under *month.*

calendar year.—See under *year.*

calibration.—The determination, in terms of an adopted *unit* and by mechanical interpolation based on values obtained by *standardization,* of the supplementary marks on a measuring instrument or device. Also the determination of the values of the *divisions* of a circle as proportional parts of a circumference.

When the length of a tape has been determined by standardization, the value of its intermediate marks may be determined by calibration, it being assumed that the tape has been divided into parts which are directly proportional to its length. See *standardization.*

Camp Colonna datum.—See under *datum.*

cardinal.*—The astronomical *directions* on the surface of the earth: north, south, east, west.

The term cardinal, without qualification, is sometimes used to indicate any or all of the above *directions,* the context giving exact meaning to its use.

Cassini map projection.—See under *map projection.*

catenary correction, tape.—See under *tape: sag or catenary correction.*

celestial equator.—See under *equator.*

celestial latitude.—See under *latitude.*

celestial longitude.—See under *longitude.*

celestial meridian.—See under *meridian.*

celestial refraction.—See under *refraction: astronomical refraction.*

celestial sphere.—A sphere of indefinitely large (infinite) radius, described around an assumed center, and upon which positions of celestial bodies are projected along radii passing through the bodies.

In surveying operations which include observations on a celestial body, the *direction* but not the distance of the celestial body from the point of observation is important. For observations on bodies within the limits of the solar system, the center of the celestial sphere is taken as coinciding with the center of the earth. For bodies outside those limits, the *annual parallax* is negligible in surveying operations, and the center of the celestial sphere may be taken as coinciding with the point of observation.

Celsius scale.—A temperature scale in which 100° marks the freezing point and 0° the boiling point of water at 760 mm. barometric pressure.

The Celsius scale is the predecessor of and is equal to the *centigrade scale* inverted. Some use has been made of Celsius scale as synonomous with *centigrade scale.*

center: reduction to.—The amount which must be applied to a *direction* observed at an *eccentric station* or to an *eccentric signal,* to reduce such *direction* to what it would be if there were no such *eccentricity.*

The computation of the reduction to center is quite similar for the two cases, the same computation form being adapted for the *correction* to a *direction* observed at an *eccentric station* as to a direction to an *eccentric signal.*

center line (United States public-land surveys).*—The line connecting opposite *quarter-section corners,* or opposite sixteenth-section corners.

center of instrument.—The point on the vertical axis of *rotation* of an instrument at the same *elevation* as the *axis of collimation* when that axis is in a horizontal position.

In a *transit* or *theodolite,* it is close to or at the intersection of the horizontal and vertical axes of the instrument.

center of oscillation (pendulum).—The position in a *compound pendulum* of the particle which corresponds to the heavy particle of an equivalent *simple pendulum.*

The *centers of suspension* and oscillation are interchangeable. If the center of oscillation is made the *center of suspension,* the former *center of suspension* becomes the new center of oscillation. This principle is the basis of design of *compound reversible pendulums.*

center of suspension (pendulum).—The fixed point about which a pendulum *oscillates.* See *center of oscillation.*

center of transit or level.—A manufacturer's term for the spindle or spindles which are in a vertical position when the instrument is in use, and about which the instrument, or part of the instrument, *rotates.*

The engineer's *transit* has two such centers; an inner center to which the *alidade* is attached, and an outer center to which the horizontal circle is attached; it is hollow and *rotates* on the inner center. The rotation of the *alidade* is spoken of as the upper motion, and the rotation of the horizontal circle as the lower motion of the instrument.

centigrade scale.—A temperature scale in which 0° marks the freezing point and 100° the boiling point of water at 760 mm. barometric pressure. See *Celsius scale.*

central meridian (State plane-coordinate system).—See under *meridian.*

centrifugal force.—The force with which a body moving under constraint along a curved path, reacts to the constraint.

Centrifugal force acts in a direction away from the center of curvature of the path of the moving body. As a force caused by the *rotation* of the earth on its axis, centrifugal force is opposed to *gravitation,* and combines with it to form *gravity.*

c. g. s. system.—The system of physical measurements in which the fundamental units of length, mass, and time are the centimeter, the gram, and the *mean solar second.*

chain.—The *unit of length* prescribed by law for the survey of the *public lands of the United States.* The chain is equivalent to 66 feet.

The chain derives its name from the *Gunter's chain,* which had the form of a series of *links* connected together by rings, a form which has been superseded by metal tapes or ribbons graduated in chains and links. The General Land Office uses steel tapes of 1, 2, 5, or 8 chains length.

chain: Gunter's.—A measuring device used in land surveying, composed of 100 metal *links* fastened together with rings, the length of the *chain* being 66 feet.

It was invented by an English astronomer, Edmund Gunter, about 1620, and is the basis for the *chain* and *link, units of length* used in the survey of the *public lands of the United States.* An advantage in measuring in *chains* is that 10 square *chains* equals 1 acre.

chaining.—The operation of measuring a distance on the earth, using a chain or tape. See *taping.*

While the *chain* as an instrument used in making land and other surveys has been superseded by the metal tape, the term chaining has continued in use where reference is to surveys of the *public lands of the United States.* For the corresponding operation in other surveys, the term *taping* is preferred. In chaining, the men who mark the tape ends are termed *chainmen.*

chainmen.—The men who mark the tape ends in *chaining.*

chambered spirit level.—See under *level.*

chart.*—A *special-purpose map* designed for purposes of navigation.

The term chart is applied chiefly to *maps* made primarily for nautical and aeronautical navigation, and to *maps* of the heavens, although the term is sometimes used to describe other *special-purpose maps.*

chart: aeronautical.*—A *chart* designed for use in navigation through the air above land or water.

An aeronautical chart shows aids and hazards to navigation. In the past, an aeronautical chart has been variously designated as an aerial navigation map, air navigation map, aerial map, aviation map, aviation chart, and air navigation chart. The use of these terms is disapproved.

chart: air navigation.—See under *chart: aeronautical chart.*

chart: aviation.—See under *chart: aeronautical chart.*

chart: bathymetric.*—A *topographic map* of the bed of the ocean.

As now published, bathymetric charts show depth curves, with areas between curves given significant color tints. Bathymetric charts are designed especially for geophysical (oceanographic) studies, but may also be used for navigation purposes.

chart: magnetic.—A *special-purpose map* depicting the distribution of one of the magnetic elements, as by isogonic lines, or of its secular change.

chart: nautical.*—A *chart* designed for use in navigation in water areas.

A nautical chart shows aids and hazards to navigation.

chromatic aberration.—See under *aberration of light (optics).*

chronograph.—An instrument for producing a graphical record of time as shown by a clock or other device.

In use, a chronograph produces a double record: the first is made by the associated clock and forms a continuous time scale with significant marks indicating periodic beats of the time keeper; the second is made by some external agency, human or mechanical, and records the occurrence of an event or of a series of events. The clock times of such occurrences are read on the time scale made by the clock. In observations for *time* and *longitude,* the clock times of star observations are recorded on the chronograph either manually by pressing a key at the instant a star is bisected by a line of the *reticle* of the telescope used in the observing, or automatically, by keeping a star bisected by a movable wire as it travels across the field of view. See *micrometer: transit.* In longitude work, the chronograph also records the time signals received from the station of known *longitude* which is used as a base.

chronometer.—A portable timekeeper with compensated balance, capable of showing *time* with extreme *precision* and *accuracy.*

Chronometers are used in scientific and engineering work (astronomy, navigation, geophysics, etc.) where *accuracy* and *precision* in the timing of observations are demanded. Chronometers are usually constructed with a special type of balance and escapement, and beat to half seconds.

chronometer: break-circuit.—A *chronometer* equipped with a device which automatically breaks an electric circuit, the breaks being recorded on a *chronograph.*

In some *chronometers,* the breaks occur every other second, on the even seconds, and a break occurs also on the fifty-ninth second to identify the beginning of the minute; in other *chronometers,* breaks occur every second except at the beginning of the minute. By recording the occurrence of events (such as star *transits*) on a *chronograph* sheet along with the *chronometer* breaks, the *chronometer* times of those occurrences are obtained.

chronometer: hack.—A *chronometer* used for visual reference, and not usually for record purposes.

In astronomical and other work, where a time recording on a *chronograph* is made, the *chronometer* controlling the recording is placed in a position as free from disturbance as possible. For use in meeting the schedule of the observations, making the necessary settings of instruments, etc., another *chronometer,* called a hack, is kept in a position where it may be easily observed.

chronometric method of determining longitude.—See under *longitude: astronomic longitude.*

circle of equal altitude.—See under *almucantar.*

circle of position.—A small circle on the *globe* (earth) at every point of which, at the instant of observation, the observed celestial body (sun, star, planet) has the same *altitude* and therefore the same *zenith distance.*

At the instant of observation the observed body is in the *zenith* of the center of the circle of position, and the point of observation is somewhere on that circle. A second observation on the same object at a different time or on a different object at the same time will determine a second and different circle of position, and if the point of observation has not been moved, it will be at an intersection of these circles. If the point of observation has moved, as may occur when on a moving ship, allowance is made for the direction and amount of the movement, and a *position* obtained for either point of observation. In navigation, a short portion of a circle of position is plotted as a straight line and termed a *Sumner line* or *line of position.*

circuit (leveling).—A continuous *line of levels,* a series of lines of levels, or a combination of lines or parts of lines of levels, such that a continuous series of measured differences of elevation extends around the circuit or loop and back to the starting point.

circuit closure (leveling).—The amount by which the algebraic sum of the measured differences of elevation around a *circuit* fails to equal the theoretical closure, zero.

circular level.—See under *level.*

cistern barometer.—See under *barometer.*

civil day.—See under *day.*

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civil time.—See under *time.*

clamping error.—See under *error.*

Clarke spheroid of 1866.—See under *spheroid.*

clinometer.—A hand instrument consisting of a tube with cross-hair, with *vertical circle* and attached *spirit level* so mounted that the inclination of the *line of sight* can be read on the circle by centering the level bubble at the instant of observation.

By means of a prism, the level bubble is viewed when looking through the observing tube at the cross-hair and object observed.

clock correction.—The quantity which is added algebraically to the time shown by a clock to obtain the time of a given *meridian.*

If the clock is slow, the *correction* is positive; if fast, negative.

clock rate.—The rate of change of a *clock correction.*

Clock rate is usually expressed as the increase or decrease of the *clock correction* per day, hour, or minute as shown on the clock face. It is called the daily or hourly rate, or rate per minute. If the *clock correction* is decreasing algebraically, the clock is gaining, and the rate is negative; if the *correction* is increasing, the clock is losing, and the rate is positive.

closing corner (United States public-land surveys).—See under *corner.*

closing error.—See under *error of closure.*

closing horizon.—See under *horizon.*

closure (leveling).—See *circuit closure (leveling).*

closure of horizon.—See under *error of closure of horizon.*

closure of traverse.—See under *error of closure, traverse.*

closure of triangle.—See under *error of closure of triangle.*

co-declination.—The complement of the *declination (astronomic)*, or 90° minus the *declination.* Also called the *polar distance.*

coefficient of refraction.—See under *refraction.*

coefficient of thermal expansion; coefficient of expansion.—The relative change (expansion or contraction) in a linear dimension of a material body corresponding to a change of 1° in the temperature of the body, expressed as a ratio.

The coefficient of expansion, as it is generally called, may be in terms of the *Centigrade, Fahrenheit,* or other thermometer scale. To a very great extent, its magnitude is peculiar to the material: a steel tape has a coefficient of expansion about 25 times as great as that of an *invar tape.* It is usually expressed as a decimal fraction, and in a measure of distance, as of a *base line,* enters as a *correction* which is a product of the coefficient of expansion of the length apparatus, the distance measured, and the difference between the temperature at which the measure was made and the temperature at which the length of the apparatus is known.

coincidence (pendulum).—An exact agreement in occurrence of a prescribed phase of a *free-swinging pendulum* beat and a prescribed phase of a clock or *chronometer* beat.

The *free-swinging pendulum* being either slightly longer or slightly shorter than the clock *pendulum,* vibrates at a different speed from the clock *pendulum,* and loses or gains a whole beat between coincidences. The elapsed time between coincidences as shown by the clock or *chronometer,* enables an observer to know the number of *vibrations* made by the *free-swinging pendulum* during that time, and thus the number made during a period between precise time determinations.

In the *gravity* work of the U. S. Coast and Geodetic Survey, coincidences are observed by noting when two lines of light come into exact agreement: one is a moving line reflected by a mirror attached to the head of a *free-swinging pendulum;* the other, a fixed line of light reflected from a mirror attached to the *pendulum* support and becoming visible each second through a shutter controlled by the *chronometer.*

coincidence method (pendulum).—The determination of the period of a *free-swinging pendulum* by observing the time interval between *coincidences* with a clock *pendulum* or *chronometer* beat.

colatitude.—The complement of the *latitude,* or 90° minus the *latitude.*

Colatitude forms one side, *zenith* to pole, of the *astronomical triangle.* It is opposite the celestial body.

collimation.—The act of making a *collimation adjustment.*

This use of the term collimation may lead to confusion, which would be avoided by employing a more extended expression.

collimation: error of.—The *angle* between the *line of collimation (line of sight)* of a telescope and its *collimation axis.*

When the *collimation adjustment* of an instrument is perfect (which is never the case), the *line of collimation* and the *collimation axis* will coincide, and the error of collimation will be zero. In practical work, the adjustment is carried to where the *error* is so small that it may be considered negligible in many classes of work; or in *precise* work, after the adjustment is made, the *residual error* is either determined by observation and applied as a *correction,* or is eliminated from the result by a suitable program of observing. Error of collimation is a *systematic error,* and in a series of observations is usually treated as being of the *constant error* type.

collimation: line of.—The line through the *second nodal point* of the objective (object glass) of a *telescope* and the center of the *reticle.* It is variously called the line of sight, sight line, pointing line, and aiming line of the instrument.

The center of the *reticle* of the *telescope* of a *transit* may be defined by the intersection of cross-hairs or by the middle point of a fixed vertical wire or of a micrometer wire in its mean position. In a leveling instrument, the center of the *reticle* may be the middle point of a fixed horizontal wire.

collimation adjustment.—The process of bringing the *line of collimation* of a *telescope* into close agreement with the *collimation axis.* Also called adjustment for collimation.

collimation axis.—The line through the *second nodal point* of the objective (object glass) perpendicular to the axis of *rotation* of the *telescope.*

In a surveyor's *transit,* the collimation axis is perpendicular to the *horizontal axis* of the *telescope.* In a leveling instrument it is perpendicular to the *vertical axis* of the instrument. When the *telescope* of a *transit* is *rotated* about its *horizontal axis,* the collimation axis describes a plane, called the *collimation plane.*

collimation plane.—The plane described by the *collimation axis* of a *telescope* of a *transit* when rotated around its *horizontal axis.*

collimation position.—A term defined in Manual of Engineering Practice No. 15, A. S. C. E., as follows: "The ideal position of the line of sight of a telescope; that is, the optical axis. See, also, Line of Sight." The ideal position of the line of sight is known as the *collimation axis.* The term collimation position as defined by the A. S. C. E. seems unnecessary, and its definition appears contradictory.

collimator.—A device consisting of a convergent *achromatic lens* with a mark placed in the plane of its principal focus, so that rays from the mark through the lens emerge along parallel lines.

The mark in a collimator may be viewed from very short distances as if it were at an infinite distance, and may therefore be used in place of a distant mark when making any adjustment of the *line of sight* (*line of collimation*) of an instrument. In adjusting a surveying instrument, the *telescope* of another surveying instrument may be used as a collimator, the *reticle* furnishing the mark; or the *telescope* of a discarded instrument may be placed on a special mounting to form a permanent installation. In some astronomical instruments, a vessel of mercury, placed directly under the instrument, is used as a collimator. A prismatic eyepiece used with such an instrument is sometimes called a collimating eyepiece.

A collimator may also be constructed of special design for a particular purpose: see *collimator: vertical.*

collimator: vertical.—A *telescope* so mounted that its *collimation axis* may be made to coincide with the *vertical* (or direction of the plumb line).

The vertical collimator serves as an optical plumb line, and may be designed for use in placing a mark on the ground directly under an instrument on a high tower; or in centering an instrument on a high tower directly over a mark on the ground.

colure: equinoctial.—The *hour circle* through the *equinoxes.*

colure: solstitial.—The *hour circle* through the *solstices.*

colures.—The *hour circles* through the *equinoxes* and the *solstices.* See *colure: equinoctial; colure: solstitial.*

comb (micrometer).—A notched scale placed at right angles to the movable wire of a *micrometer,* and so designed that one turn of the micrometer screw will move the micrometer wire across one notch of the comb; the central notch of the comb in conjunction with the zero of the micrometer head furnishes a fiducial point from which all micrometer readings are reckoned.

The comb is used for keeping count of whole turns of the micrometer screw, parts of turns being read on the graduated micrometer head.

Committee Meter.—See under *meter.*

comparator.—An instrument or apparatus for measuring a dimension in terms of a *standard.*

In *plane* and *geodetic surveying,* a comparator may be an instrument for comparing *standards of length;* for subdividing such *standards;* or for determining a standard length of a measuring device (bar, tape, etc.). A field comparator or comparator base is a short line whose length is measured with accuracy and *precision,* and used to check the lengths of apparatus (tapes) used in the actual field operations.

There are special types of comparators used in astronomic and photogrammetric work, and in various kinds of laboratory work.

comparator: field.—See under *comparator.*

comparator base.—See under *comparator.*

compass: prismatic.—A small magnetic compass held in the hand when in use, and equipped with peep sights and glass prism so arranged that the *magnetic bearing* or *azimuth* of a line can be read at the same time that the line is sighted over.

compass: solar.—A surveying instrument which effects the instantaneous mechanical solution of the *astronomical triangle* (sun-zenith-pole), and permits the establishment and surveying of the *astronomic meridian* or *astronomic parallel* directly by observation.

Originally invented and used for the establishment of *astronomic meridians* and *parallels* in the survey of the *public lands of the United States,* the solar compass has been replaced by the *solar attachment* in combination with a *transit,* or by the *solar transit.*

compass: sun.—A navigation instrument for determining the direction of the *astronomic meridian* mechanically and instantaneously from an observation on the sun.

A good example of a sun compass is the one designed by A. H. Bumstead of the National Geographic Society and used by R. E. Byrd in aeronautical navigation in the polar regions. It consists of a mean-time clock with a 24-hour dial, an hour hand with a shadow pin at one end, and graduated circles for *latitude* and *azimuth* setting. In use, the clock is set for *latitude* so that the plane of its face is parallel to the plane of the *equator,* the hour hand (it has only the one hand) is set to show local time, and the whole is oriented till the pin on the hour hand casts a shadow down the middle of the hand. In this position, the lubber line will be in the local *meridian.* The term sun compass is preferred for the navigation instrument, to distinguish it from the *solar compass,* a surveying instrument which attains a similar result.

compass: surveyor's.—An instrument for determining the *magnetic azimuth* of a line of sight by means of a sighting device, a graduated horizontal circle, and a pivoted magnetic needle.

The surveyor's compass used on the early land surveys in this country employed a pair of peep sights to define the *line of sight,* and was usually mounted on a single leg, called a *Jacob's staff.* This instrument has been completely displaced by the surveyor's *transit,* and the *solar transit.*

compass rule, balancing survey.—See under *balancing a survey.*

compensated géoid.—See under *geoid.*

compensating base-line measuring apparatus.—See under *base apparatus.*

compiled map.—See under *map.*

complement of angle.—See under *angle.*

composite map.—See under *map.*

compound pendulum.—See under *pendulum.*

compression (of the earth).—See under *flattening of the earth.*

concluded angle.—See under *angle.*

condition equation.—See under *equation.*

conformal (isometric) latitude.—See under *latitude.*

conformal map projection.—See under *map projection.*

conformality.—The unique property of *conformal map projections,* in which all small or elementary figures on the surface of a sphere retain their original forms (shapes) on the *map.*

conic map projection.—See under *map projection.*

constant: level.—The amount by which the actual *line of sight* through a *leveling instrument* (when the bubble is centered in its vial) departs from the truly horizontal line through the center of the instrument, computed in millimeters per millimeter of *stadia interval.*

In case leveling rods graduated in yards instead of meters are used, the level constant, *C,* would be expressed in milliyards per milliyard of *stadia interval.*

constant: stadia (leveling).—The constant which is multiplied by the *stadia interval* to obtain the length of a sight in meters. Also the constant by means of which the sum of the stadia intervals for all sights of a *running* is converted to the length of the running in kilometers.

In case yard rods are in use, the resulting lengths will be in yards and kiloyards.

constant error.—See under *error.*

constant of gravitation.—See under *gravitation.*

contact base-line measuring apparatus.—See under *base apparatus.*

contact correction, transit micrometer.—A quantity applied to the *chronograph* record of a star *transit* observed with the aid of a *transit micrometer* to allow for the time required for the contact spring to cross one-half of the width of a contact strip in the head of the *micrometer.*

In order to insure a satisfactory record, the contact strips are given appreciable width, and as the micrometer wire travels from different sides of the instrument for *upper* and *lower culmination stars,* and also before and after reversal of the instrument, the contact spring produces a record sometimes from one edge of a contact strip and sometimes from the other. The contact correction is intended to reduce each observation to the middle of the contact strip which records it.

contact-slide base-line measuring apparatus.—See under *base apparatus.*

contact vernier.—See under *vernier.*

contour.—An imaginary line on the ground, all points of which are at the same *elevation* above a specified *datum* surface.

A contour is illustrated by the shore line of an imaginary body of water, whose surface is at the *elevation* represented by the contour. A contour forming a closed loop around lower ground is called a depression contour. The datum surface most generally used for contours in this country is *mean sea level.*

contour interval.—The difference in *elevation* of two adjacent *contours.* The difference of *elevations* represented by adjacent *contour lines.*

contour line.—A line on a *map* representing a *contour.*

contour map.—See under *map.*

control: basic.—In general, coordinated and correlated position data forming a framework to which detail surveys are adjusted.

Basic control may be either horizontal or vertical; it is usually executed with greater *precision* and *accuracy* than is required for dependent surveys. The basic control for the *Topographic Map of the United States* consists of *first-* and *second-order triangulation* and *traverse* and *first-* and *second-order leveling.*

control: cadastral (United States public-land surveys).—See under *cadastral control (United States public-land surveys).*

control: geodetic.—A system of *control stations* established by *geodetic* methods.

Geodetic control data are first determined in the form of *geodetic coordinates* and *azimuths,* which are now sometimes transposed into plane-coordinate data on a State system, before being used as bases for local surveys.

control: national control survey nets.—The two *control survey* nets being extended over the area of the United States by the U. S. Coast and Geodetic Survey for the control of *nautical charts* and *topographic maps,* and comprising:

1. The horizontal control survey net consisting of arcs of *first-* and *second-order triangulation,* and lines of *first-* and *second-order traverse,* a few of which have been executed by the U. S. Geological Survey, the Corps of Engineers, and other organizations. The data derived in this survey are being coordinated and correlated on the *North American datum of 1927.*

2. The vertical control survey net consisting of lines of *first-* and *second-order spirit leveling* which determine the *elevations* of thousands of *bench marks* above a common *datum, mean sea level.* This net includes lines of levels run by the U. S. Geological Survey, the Corps of Engineers, and other organizations.

control station.—A point on the ground whose *position* (horizontal, vertical) is used as a base for a dependent survey.

control survey.—A survey which provides *positions* (horizontal, vertical) of points to which supplementary surveys are adjusted.

The fundamental control survey of the United States provides the *geographic positions* (and *plane coordinates*) of thousands of *triangulation* and *traverse stations* and the *elevations* of thousands of *bench marks* which are used as the bases for *hydrographic surveys* of the coastal waters, for the control of the *topographic survey* of the United States, and for the control of many State, city, and private surveys.

control surveys: first-order.—See under *first-order work (control surveys).*

control surveys: second-order.—See under *second-order work (control surveys).*

convergence of meridians.—See under *meridian.*

conversion factor.—See under *factor.*

Conybeare leveling rod.—See under *leveling rod.*

coordinate protractor.—See under *protractor.*

coordinates (general).—Linear or angular quantities, or both, which designate the *position* of a point in relation to a given reference frame.

There are two general divisions of coordinates used in surveying: *polar coordinates* and *rectangular coordinates.* These may each be subdivided into three classes: *plane coordinates, spherical coordinates,* and *space coordinates.*

coordinates: astronomic.—Quantities which define the *position* of a point on the *geoid* with reference to the planes of the *celestial equator* and of a selected *celestial meridian.* See *latitude: astronomic; longitude: astronomic.*

coordinates: geocentric (terrestrial).—Quantities defining the *position* of a point on the earth by means of the *angles* made by a line from the center of the earth to the point with the planes of the *celestial equator* and of a selected initial *geodetic meridian.*

See *latitude: geocentric.* The term geocentric longitude is never used, as the quantity which it would designate is the same as *geodetic longitude.*

coordinates: geodetic.—Quantities which define the horizontal *position* of a point on the *spheroid of reference* with respect to the planes of the *geodetic equator* and of a selected *geodetic meridian.* See *latitude: geodetic; longitude: geodetic.*

coordinates: geographic.—An inclusive term, used to designate both *geodetic coordinates* and *astronomic coordinates.*

coordinates: grid.—Two distances which fix the *position* of a point on a *grid:* the perpendicular distance to the point from the Axis of *Y,* termed the abscissa or *x* coordinate; and the perpendicular distance from the Axis of *X,* termed the ordinate or *y* coordinate.

In surveying operations, the nominal *origin* at the intersection of the axes is usually given large numerical *coordinates,* so the inconvenience of using negative *coordinates* will be avoided. *Geodetic coordinates (latitudes* and *longitudes)* may be transformed into grid coordinates, and all survey computations relating to them then made by the methods and formulas of *plane surveying*. See *State coordinate systems.*

coordinates: origin of.—A point in a system of *coordinates* which serves as an initial in computing its elements or in prescribing its use.

The term, origin of coordinates, has several definitions, each so well-established in use that a single definition cannot be prescribed to the exclusion of the others. However, the following are given in the order of preferred use, but to avoid misunderstanding the use should be defined by stating the *position* of the origin in the system and giving the numerical *coordinates* assigned it.

1. The origin of coordinates is the point of intersection of the coordinate axes, from which the *coordinates* are reckoned. In mathematical treatises this origin is usually given the *coordinates* 0, 0; in surveying work, however, it is standard practice to give this origin *coordinates* having large positive numerical values, thereby avoiding the use of negative *coordinates*. See *State coordinate systems.*

2. The origin of coordinates is the point to which the coordinate values 0, 0 are assigned, irrespective of its *position* with reference to the axes.

3. The origin of coordinates is the point from which the computation of the elements of the coordinate system (projection) proceeds.

coordinates: plane-rectangular.—The perpendicular distances (*coordinates*) of a point from a pair of axes which intersect at right angles, reckoned in the plane defined by those axes.

Plane-rectangular coordinates are usually calculated from data which are in the form of *polar coordinates*, that is, distance and *direction* (*bearing* or *azimuth*) from a previously determined point. For example, the computation of *latitudes* and *departures* in land surveying. The methods used are based on plane trigonometry and geometry. The *position* of a point on the earth may be defined by plane-rectangular coordinates on a tangent plane (*local system of plane coordinates*), or on a so-called *conic* or *cylindrical map projection*, such as are used in the *State plane-coordinate systems.*

coordinates: polar (general).—The distance and *direction* from a central point of reference to a point whose position is being defined.

The point of reference is termed the pole or origin; the line (distance) connecting the origin with the point whose position is being defined is the radius vector; and the *angle* between the fixed line to which the *direction* is referred and the radius vector is the vectorial angle. In surveying operations, observations are usually put in the form of polar coordinates as a first step in the computation of *plane* or *spherical coordinates*. For example, computations of *geodetic positions* (*latitudes* and *longitudes*) are based on *azimuths* and distances from known positions.

coordinates: rectangular.—*Coordinates* on any system in which the axes of reference intersect at right angles.

A system of rectangular coordinates may be plane, curved (spherical), or spatial. See *coordinates: plane-rectangular; coordinates: geodetic; coordinates: rectangular space; etc.*

coordinates: rectangular space.—The perpendicular distances of a point from planes defined by each pair of a set of three axes which are mutually perpendicular to each other at a common point or origin.

In photogrammetry, space coordinates are also termed survey coordinates, and are the x and y *coordinates* which define the horizontal position of a point on a ground system, and the z coordinate, which is the *elevation* of the point with reference to the ground system.

coordinates: spherical.—Two quantities, angular or linear, or both, on a sphere, defining the *position* of a point with reference to two *great circles* which form a pair of axes, or with reference to an *origin* and a *great circle* through the point.

The term spherical coordinates includes *coordinates* on any surface approximating a sphere. See *coordinates: geographic; coordinates: geodetic; coordinates: astronomic.*

coordinates: vertical.—The vertical distance (*elevation*) of a point above or below a surface of reference (*datum*).

The vertical coordinate of a point may be plus or minus, according to whether the point is above or below the *datum;* the *datum* may be assigned a large positive *elevation*, so that all *elevations* referred to it will be plus. Instead of *elevation*, the term height is sometimes used.

coordination.—The placing of survey data on the same coordinate system or *datum.*

Coordination does not imply the *adjustment* of observations to remove *discrepancies*. Two field surveys over the same area may be coordinated by computation on the same *datum*, but there may remain between them *discrepancies* that can be removed only by *correlation.*

corner.—A point on a *land boundary*, at which two or more boundary lines meet.

Not the same as *monument*, which refers to the physical evidence of the corner's location on the ground.

corner (United States public-land surveys).*—A point on the surface of the earth, determined by surveying process, marking an extremity of a boundary of a subdivision of the public lands, usually at the intersection of two or more surveyed lines; often incorrectly employed to denote the physical structure, or *monument*, erected to mark the corner point.

Corners are described in terms of the points they represent. Thus:

township corner.—A corner at the extremity of a *township* boundary.

section corner.—A corner at the extremity of a *section* boundary.

quarter-section corner.—A corner at an extremity of a boundary of a *quarter section*, midpoint between or 40 chains from the controlling section corners, depending on location within the *township.*

sixteenth-section corner.—A corner at an extremity of a boundary of a *quarter-quarter section;* midpoint between the controlling corners on the *section* or *township* boundaries.

meander corner.—A corner marking the intersection of a *township* or *section* boundary and the *mean high-water* line of a body of water.

standard corner.—A corner on a *standard parallel* or *base line.*

corner: closing (United States public-land surveys).*—A *corner* at the intersection of a surveyed boundary with a previously established *boundary line.*

In the survey of the public land of the United States, when the line connecting the last *section corner* and the objective corner on an established *township* boundary departs from the *astronomic meridian* by more than the allowable deviation, the line being surveyed is projected on *cardinal* to an intersection with the *township* boundary, where a closing corner is established and connection made to the previously established corner. Closing corners are established at the intersection of a line being surveyed with a previously established *township* boundary in order to avoid excessive deviation from *cardinal* which might be required to connect with the objective corner on that boundary. Closing corners are also established at the intersection of a *township, range,* or *section line* with the boundary of a previously surveyed and segregated tract of land, such as a private land claim, mineral claim, etc.

corner: existent (United States public-land surveys).*—A *corner* whose *position* can be identified by verifying the evidence of the *monument,* or its *accessories,* by reference to the description that is contained in the field notes, or where the point can be located by an acceptable supplemental survey record, some physical evidence, or testimony.

Even though its physical evidence may have entirely disappeared, a *corner* will not be regarded as lost if its *position* can be recovered through the testimony of one or more witnesses who have a dependable knowledge of the original location.

corner: lost (United States public-land surveys).*—A *corner* whose *position* cannot be determined, beyond reasonable doubt, either from traces of the original marks or from acceptable evidence or testimony that bears upon the original *position,* and whose location can be restored only by reference to one or more inter-dependent corners.

corner: obliterated (United States public-land surveys).*—A *corner* at whose point there are no remaining traces of the *monument,* or its *accessories,* but whose location has been perpetuated, or the point for which may be recovered beyond reasonable doubt, by the acts and testimony of the interested landowners, competent surveyors, or other qualified local authorities, or witnesses, or by some acceptable record evidence.

A position that depends upon the use of collateral evidence can be accepted only as duly supported, generally through proper relation to known corners, and agreement with the field notes regarding distances to natural objects, stream crossings, *line trees,* and off-line tree blazes, etc., or unquestionable testimony.

corner: witness (United States public-land surveys).*—A monumented survey point near a *corner,* established as a *reference mark* when the corner is so situated as to render its monumentation or ready use impracticable.

A witness corner is marked in a prescribed manner, comparable with that for the true *corner.*

corner accessories (United States public-land surveys).—See under *accessories.*

correction.—A quantity which is applied to an observation or function thereof, to diminish or eliminate the effects of *errors* and obtain an improved value of the observation or function. It is also applied to reduce an observation to some arbitrary standard.

The correction corresponding to a given *error* is of the same magnitude but of opposite sign. The signs are given by the following equation: improved value = observed value + correction.

See under *error: residual error.*

correction: adjustment (leveling).—That correction which is applied to an *orthometric elevation* to produce an *adjusted elevation,* for the purpose of eliminating the effects of *circuit closures.*

correction: index (leveling).—That correction which must be applied to an observed difference of elevation to eliminate the *error* introduced into the observations when the zero of the graduations on one or both *leveling rods* does not coincide exactly with the actual physical foot or bottom surface of the rod.

correction: level (leveling).—That correction which is applied to an observed difference of elevation to correct for the *error* introduced by the fact that the *line of sight* through the *leveling instrument* is not absolutely horizontal when the bubble is centered in its vial.

correction: orthometric.—That correction which is applied to a *preliminary elevation* to correct for the *error* introduced by the fact that level surfaces at different *elevations* are not exactly parallel.

correction: rod (leveling).—That correction which is applied to an observed difference of elevation to correct for the *error* introduced when the *leveling rods* are not actually of the length indicated by the *graduations.*

correction: temperature (leveling).—That correction which is applied to an observed difference of elevation to correct for the *error* introduced when the temperature at which the *leveling rods* are used in the field is different from the temperature at which they were standardized. See, also, *standardization.*

correction for inclination of the horizontal axis.—See under *inclination of the horizontal axis.*

correction for run of micrometer.—See under *micrometer.*

correlate equation.—See under *equation.*

correlation.—The removal of *discrepancies* that may exist among survey data, so that all parts are interrelated without apparent *error.*

The terms *coordination* and correlation are usually applied to the harmonizing of *surveys* of adjacent areas or of different *surveys* over the same area. Two or more such *surveys* are coordinated when they are computed on the same *datum;* they are correlated when they are adjusted together.

county map.—See under *map.*

course (general).—This term has many meanings. In *surveying* it has been used to designate the *bearing* of a line; the length of a line; and the combination, *bearing* (or *azimuth*) and length of a line. In *control surveying,* its use can and should be avoided, but if used, it should be with the inclusive meaning, *azimuth* and length of line. It is better to use the two distinct and definite terms, *azimuth* and length of line. The following are definitions of course as used in current technical literature:

course (geography).—A route on the earth along which a river flows; the river itself.

course (land surveying).—The *bearing* of a line.

course (navigation).—The *azimuth* or *bearing* of a line along which a ship is to travel or does travel.

course (transit traverse).—The *azimuth* and length of a line, considered together.

crystal clock.—The crystal clock is a relatively new device for keeping accurate *time.* It consists essentially of a generator of constant frequency controlled by a resonator made of quartz crystal, with suitable means for producing continuous *rotation* controlled by it to operate time indicating and related mechanisms.

The above description is quoted directly from a paper, The Crystal Clock, by W. A. Marrison, published in the Proceedings of the National Academy of Sciences, July 15, 1930. The crystal clock has been used with considerable advantage over other types of portable clocks and *chronometers* in scientific work, such as *gravity* observations, where *time* intervals must be measured with the greatest possible *accuracy* and *precision.*

culmination.—The position of a heavenly body when at highest apparent *altitude;* also, for a heavenly body which is continually above the *horizon*, the position of lowest apparent *altitude.*

Culmination occurs when the body *transits* the local *meridian:* upper culmination at the upper branch of the *meridian;* lower culmination at the lower branch. As an observer approaches a pole of the earth, culmination of the fixed stars becomes less noticeable, disappearing when the pole is reached. Under some conditions, for bodies within the solar system, culmination may be largely obscured by changes in *declination.* At one time, moon culminations were extensively used in determining *astronomic longitude.*

cumulate.—A term proposed for a type of *error* which tends to accumulate in direct proportion to occurrence.

This type of *error* is covered by the expression *systematic error,* and there is no need for a new term. The use of cumulate should be avoided.

curvature correction (astronomy).—A *correction* applied to the mean of a series of observations on a star or planet, to take account of the divergence of the apparent path of the star or planet from a straight line.

Observations on a star for the purpose of determining the value of a *micrometer* are subject to a correction for curvature, as also are some *azimuth* observations. The *correction* to reduce a *latitude* observation on a star close to but not on the *meridian* to what it would be if the star were on the *meridian* may be considered a correction for curvature.

curvature correction (geodesy).—The *correction* applied in some *geodetic* work to take account of the divergence of the surface of the earth (*spheroid*) from a plane.

In *geodetic spirit leveling,* the effects of curvature and of *atmospheric refraction* are considered together, and tables have been prepared from which combined *corrections* can be taken.

curve: degree of.—The number of degrees of angular measure at the center of a circle subtended by a chord 100 feet in length.

In highway surveying, a 100-foot arc is sometimes used instead of a 100-foot chord in defining degree of curve.

curve: easement.—A *spiral curve.*

curve: point of compound curvature.—The point on a line survey where a circular curve of one radius is tangent to a circular curve of a different radius, both curves lying on the same side of their common tangent. Also termed the P. C. C.

curve: point of curvature.—The point in a line survey where a tangent ends and a circular curve begins. Also called point of curve, and P. C.

It is the point where a straight line in a survey changes to a circular curve. See *curve: point of tangency.*

curve: point of intersection.—The point where the two tangents of a circular curve meet. Also called the vertex of curve, and the P. I.

curve: point of tangency.—The point in a line survey where a circular curve ends and a tangent begins. Also called point of tangent, and P. T.

The point of tangency and point of curve are both points of tangency, their different designations being determined by the direction of progress along the line. The *point of curvature* is reached first.

curve: spiral.—A curve of varying radius connecting a circular curve and a tangent, or two circular curves whose radii are respectively longer and shorter than its own extreme radii. Also called a transition curve and an easement curve.

curve: transition.—A *spiral curve.*

curve: vertex of.—See under *curve: point of intersection.*

curve of alignment.—A line connecting two points on the surface of the *spheroid,* and defined by the condition that at every point the *azimuths* of the two end points of the line differ by exactly 180°.

A curve of alignment is a line of double curvature slightly less in length than the *normal section lines* connecting its two end points.

cut-off cylinder.—An accessory apparatus, used in *standardization* operations to refer the end of a base tape or bar standard to a ground mark.

The cut-off cylinder is a laboratory device, consisting essentially of a short rigid bar, so equipped and mounted that it forms a direct connection between the apparatus being tested and a permanent ground monument; its length and inclination provide the means for determining the relative positions of the *fiducial marks* on the base tape or bar and on the ground monument.

cylindrical equal-area map projection.—See under *map projection.*

cylindrical equal-spaced map projection.—See under *map projection.*

cylindrical map projection.—See under *map projection.*

D

datum.—Any numerical or geometrical quantity or set of such quantities which may serve as a reference or base for other quantities.

For a group of statistical references, the plural form is data: as *geographic* data for a list of *latitudes* and *longitudes.* Where the concept is geometrical and particular, rather than statistical and inclusive, the plural form is datums, as, for example, two *geodetic datums* have been used in this country in recent years.

datum (geodetic).*—A *datum* consisting of 5 quantities: the *latitude* and the *longitude* of an initial point, the *azimuth* of a line from this point, and two constants necessary to define the terrestrial *spheroid.*

It forms the basis for the computation of horizontal *control surveys* in which the curvature of the earth is considered.

datum (leveling).—A *level surface* to which heights are referred.

The *elevation* of the *datum* is usually, but not always, zero (0). The generally adopted *datum* for leveling operations in the United States is *mean sea level.* For local surveys, where a sea-level connection is not available, an arbitrary *datum* may be adopted and defined in terms of an assumed *elevation* for some physical mark (*bench mark*). A *datum* for *spirit leveling* is not a plane, and the term datum plane is incorrectly used in such connection. See, also, *datum: tidal.*

datum: Camp Colonna.—The *geodetic datum* defined by the following *geographic position* and *azimuth* on the *Clarke spheroid of 1866*:

	°	′	″
Latitude of Camp Colonna	67	25	05.11 N.
Longitude of Camp Colonna	140	59	13.50 W.
Azimuth from Camp Colonna to South Meridian	0	00	00

The above position and *azimuth* are based on astronomical observations made in 1890, the *longitude* being determined by the moon-culmination method.

datum: Golofnin Bay.—The *geodetic datum* defined by the following *geographic position* and *azimuth* on the *Clarke spheroid of 1866:*

	°	′	″
Latitude of Golofnin Bay long. station	64	27	11.461 N.
Longitude of Golofnin Bay long. station	162	52	13.700 W.
Azimuth from Golofnin Bay long. station to azimuth mark	180	00	42.9

The above position and *azimuth* based on astronomical observations made in 1899, the *longitude* being determined by the *chronometric method.*

datum: Kripniyuk-Kwiklokchun.—The *geodetic datum* defined by the following *geographic position* and *azimuths* on the *Clarke spheroid of 1866*:

	°	′	″
Latitude of Kripniyuk astro. station	62	20	06.58 N.
Longitude of Kripniyuk astro. station	165	19	27.12 W.
Azimuth from Kripniyuk astro. station to station Tent	180	00	00.0
Azimuth from Kwiklokchun astro. station to station Camp	0	00	00.0

The above position is based on *weighted means* of astronomical determinations made in 1898, the *longitudes* by the *chronometric method.*

datum: Luzon.—The *geodetic datum* which is defined by the following *geographic position* and *azimuth* on the *Clarke spheroid of 1866:*

	°	′	″
Latitude of triangulation station Balanacan	13	33	41.000 N.
Longitude of triangulation station Balanacan	121	52	03.000 E.
Azimuth, triangulation station Balanacan to triangulation station Baltasar	9	12	37.000

The Luzon datum was adopted in 1911 and was derived from observations on the Island of Luzon. It has been extended to all parts of the Philippine Islands, except a few remotely situated islands. See U. S. Coast and Geodetic Survey Field Engineers Bulletin, December 1938, page 20.

datum: New England.—Identical with the *geodetic datum* for which the name *United States standard datum* was adopted in 1901, which name was later changed to *North American datum.* Before 1901 this *datum* was defined by the following *geographic position* and *azimuth* on the *Clarke spheroid of 1866:*

	°	′	″
Latitude of triangulation station Principio	39	35	36.692 N.
Longitude of triangulation station Principio	76	00	16.407 W.
Azimuth, triangulation station Principio to triangulation station Turkey Point	1	34	36.413

See U. S. Coast and Geodetic Survey Report for 1879, Appendix 8, pages 112–114.

datum: North American.*—The *geodetic datum* which is defined by the following *geographic position* of triangulation station Meades Ranch and the *azimuth* from that station to station Waldo, on the *Clarke spheroid of 1866:*

	°	′	″
Latitude of Meades Ranch	39	13	26.686 N.
Longitude of Meades Ranch	98	32	30.506 W.
Azimuth, Meades Ranch to Waldo	75	28	14.52

The North American datum is identical with the *United States standard datum,* the name of the *datum* being changed in 1913 when its adoption by the governments of Canada and of Mexico for their control surveys gave it an international character.

datum: North American datum of 1927.*—The *geodetic datum* which is defined by the following *geographic position* of triangulation station Meades Ranch and the *azimuth* from that station to station Waldo, on the *Clarke spheroid of 1866:*

	°	′	″
Latitude of Meades Ranch	39	13	26.686 N.
Longitude of Meades Ranch	98	32	30.506 W.
Azimuth, Meades Ranch to Waldo	75	28	09.64

Geodetic positions on the North American datum of 1927 are derived from the above *geographic position* and *azimuth* through a readjustment of the *triangulation* of the entire country, in which *Laplace azimuths* were introduced, and new methods of adjustment were used (*Bowie method*).

datum: Old Hawaiian.—The *geodetic datum* which is defined by the following *geographic position* and *azimuth* on the *Clarke spheroid of 1866:*

	°	′	″
Latitude of triangulation station Oahu west base	21	18	13.89 N.
Longitude of triangulation station Oahu west base	157	50	55.79 W.
Azimuth, triangulation station Oahu west base to triangulation station Oahu east base	291	29	36.0

The Old Hawaiian datum is based on an adjusted *latitude* derived from a number of *astronomic latitudes* in various parts of the islands, and an *astronomic longitude* obtained from observations of lunar *culminations,* star *occultations,* etc. See U. S. Coast and Geodetic Survey Special Publication No. 156, Triangulation in Hawaii.

datum: Panama-Colon.—The *geodetic datum* which is defined by the following *geographic position* and *azimuth* on the *Clarke spheroid of 1866:*

	°	′	″
Latitude of triangulation station Balboa Hill	9	04	57.637 N.
Longitude of triangulation station Balboa Hill	79	43	50.313 W.
Azimuth, triangulation station Balboa Hill to triangulation station Salud	185	02	39.54

See U. S. Coast and Geodetic Survey Field Engineers Bulletin, December 1938, page 23.

datum: Port Clarence.—The *geodetic datum* defined by the following *geographic position* and *azimuth* on the *Clarke spheroid of 1866*:

	°	′	″
Latitude of Port Clarence astro. station	65	16	40.18 N.
Longitude of Port Clarence astro. station	166	50	08.065 W.
Azimuth from Port Clarence astro. station to azimuth mark	0	06	17.0

The *latitude* was determined astronomically in 1900; the *longitude* is an assumed value, the astronomically-determined value being 166° 50′ 45.60″; the *azimuth* was derived from *time* observations.

datum: Pribilof Islands datums.—See under *datum: St. George Island: St. Paul Island.*

datum: Puerto Rico.—The *geodetic datum* which is defined by the following *geographic position* and *azimuth* on the *Clarke spheroid of 1866:*

	°	′	″
Latitude of triangulation station Cardona Island lighthouse	17	57	31.400 N.
Longitude of triangulation station Cardona Island lighthouse	66	38	07.530 W.
Azimuth, triangulation station Cardona Island lighthouse to triangulation station Ponce southwest base	128	36	26.2

Adopted in 1901 or soon thereafter, the Puerto Rico datum is derived from observations on the Island of Puerto Rico and the Virgin Islands. See U. S. Coast and Geodetic Survey Field Engineers Bulletin, December 1938, page 22.

datum: St. George Island.—The *geodetic datum* defined by the following *geographic position* and *azimuth* on the *Clarke spheroid of 1866*:

	°	′	″
Latitude of St. George Island astronomic station	56	36	11.31 N.
Longitude of St. George Island astronomic station	169	32	36.00 W.
Azimuth from St. George Island astronomic station to meridian mark	0	00	06

The above *latitude* and *azimuth* are based on independent astronomical determinations. The *longitude* is based on *longitudes* of St. George Island and St. Paul Island astronomic stations, which were determined by the *chronometric method*, a *weighted mean* being obtained through *triangulation* connecting the two *islands*.

datum: St. Michael.—The *geodetic datum* defined by the following *geographic position* and *azimuth* on the *Clarke spheroid of 1866*:

	°	′	″
Latitude of St. Michael astro. station	63	28	41.51 N.
Longitude of St. Michael astro. station	162	01	06.00 W.
Azimuth from St. Michael astro. station to azimuth mark	359	59	55.6

The above position depends on astronomical observations made in 1891, the *longitude* being determined by moon-*culmination* and star-*occultation* methods.

datum: St. Paul Island.—The *geodetic datum* defined by the following *geographic position* and *azimuth* on the *Clarke spheroid of 1866*:

	°	′	″
Latitude of St. Paul Island astro. station	57	07	16.86 N.
Longitude of St. Paul Island astro. station	170	16	24.00 W.
Azimuth from St. Paul Island astro. station to azimuth mark	179	59	12

The above *latitude* and *azimuth* are based on independent astronomical determinations. The *longitude* is based on *longitudes* of the St. Paul Island and St. George Island astronomic stations, which were determined by the *chronometric method*, a *weighted mean* being obtained through *triangulation* connecting the two *islands*.

datum: Standard (California) astronomical datum of 1885.—The *geodetic datum* which is defined by the following *geographic position* and *azimuth* on the *Clarke spheroid of 1866:*

	°	′	″
Latitude of triangulation station Mt. Helena	38	40	04.260 N.
Longitude of triangulation station Mt. Helena	122	38	01.410 W.
Azimuth, triangulation station Mt. Helena to triangulation station Mt. Diablo	324	01	31.04

The determination of this *datum* is described in U. S. Coast and Geodetic Survey Report for 1885, Appendix 9, page 464. Its designation is taken from the so-called "old registers" of the Division of Geodesy. It is identical with the "Yolo base datum" used in the report on the California-Nevada boundary line, U. S. Coast and Geodetic Survey Report for 1900, Appendix 3, note on page 346.

datum: tidal.—A *datum* defined by a phase of the tide. See *datum (leveling)*.

When used as reference surface for hydrographic surveys, tidal datums are termed datum planes; however, they are not planes and are not treated as planes, but as level surfaces, which are curved. The tidal datum in most general use in *geodetic* work is *mean sea level.* In *land surveying,* where boundaries and riparian rights are involved, *mean high water* and *mean low water* are sometimes tidal datums of considerable importance. See *island; shore.*

datum: Transcontinental Triangulation.—The *geodetic datum* which is defined by the following *geographic position* and *azimuth* on the *Clarke spheroid of 1866:*

	°	′	″
Latitude of triangulation station Hays	38	54	50.18 N.
Longitude of triangulation station Hays	99	16	16.73 W.
Azimuth, triangulation station Hays to triangulation station La Crosse	359	44	19.00

The determination of this *datum* is described in U. S. Coast and Geodetic Survey Special Publication No. 4, The Transcontinental Triangulation and the American Arc of the Parallel, 1900, and was adopted and used for scientific studies reported in that publication and in Special Publication No. 7, The Eastern Oblique Arc of the United States and the Osculating Spheroid, 1902. It served no other purposes than stated above and no formal designation was given it.

datum: Unalaska.—The *geodetic datum* which is defined by the following *geographic position* and *azimuth* on the *Clarke spheriod of 1866:*

	°	′	″
Latitude of Unalaska astronomic station	53	52	36.45 N.
Longitude of Unalaska astronomic station	166	32	05.55 W.
Azimuth, Unalaska astronomic station to Observatory station	180	00	00

The above *datum* is based on astronomical observations made in 1896, the *longitude* being determined by the *chronometric method.*

datum: Valdez.—The *geodetic datum* defined by the following *geographic position* and *azimuth* on the *Clarke spheroid of 1866:*

	°	′	″
Latitude of station Pete	60	22	44.440 N.
Longitude of station Pete	145	23	48.560 W.
Azimuth from station Pete to azimuth mark	179	44	35. 4

The *geographic position* of Pete is derived through triangulation connections from the astronomic latitude of Orca astronomic station, 1898, and the astronomic longitude of Valdez longitude station, determined by telegraph in 1905. The azimuth, Pete to azimuth mark, is an astronomic azimuth.

datum: Yakutat.—The *geodetic datum* defined by the following *geographic position* and *azimuth* on the *Clarke spheroid of 1866:*

	°	′	″
Latitude of Yakutat astronomic station	59	33	50.50 N.
Longitude of Yakutat astronomic station	139	47	15.60 W.
Azimuth from Yakutat astronomic station to azimuth mark	0	00	19.5

The above position and *azimuth* were determined astronomically in 1892, the *longitude* by the *chronometric method.*

datum: Yukon.—The *geodetic datum* which is defined by the following *geographic position* and *azimuth* on the *Clarke spheroid of 1866:*

	°	′	″
Latitude of triangulation station Boundary	64	40	51.42 N.
Longitude of triangulation station Boundary	141	00	00.00 W.
Azimuth, triangulation station Boundary to triangulation station Bald	270	00	00.0

This *datum* is based on a single astronomic *station* near the crossing of the 141st Meridian and the Yukon River, and was adopted for use in computing the *triangulation* along that part of the Alaska-Canada boundary defined as being the 141st Meridian.

Davidson meridian instrument.—See under *meridian telescope.*

day.—A measure of *time* based upon the *rotation* of the earth on its axis with respect to (1) the *vernal equinox,* giving the sidereal day, and (2) the sun, giving the solar day.

day: apparent solar.—The interval of *time* from a *transit* of the sun across a given *meridian* to its next successive *transit* across the same *meridian.*

As the motion of the sun is not uniform, apparent solar days vary in length through the *year,* the maximum deviation from a *mean solar day* amounting to not quite a half minute in either direction.

day: astronomical.—A *solar day* beginning at noon.

The astronomical day may be based on either *apparent solar time* or on *mean solar time.* It begins 12 hours later than the *civil day* of the same date. Prior to 1925, the astronomical day was used as a reference in the American Ephemeris and Nautical Almanac. In 1925, and since then, the *civil day* has been used instead. An exception to the above practice is found in the American Practical Navigator (Bowditch), in the 1936 edition of which astronomical day is defined as above, while in the 1938 edition it is defined as commencing at midnight, agreeing with the *civil day.* This second definition of the term is not needed, and its use is apt to produce confusion.

day: civil.—A *solar day* beginning at midnight.

The civil day may be based on either *apparent solar time* or *mean solar time;* it begins 12 hours earlier than the *astronomical day* of the same date.

day: mean solar.—The interval of *time* from a *transit* of the *mean sun* across a given *meridian* to its next successive *transit* across the same *meridian.*

The mean solar day is derived from the average length of the *apparent solar day* throughout the *year.* See *time: mean solar.*

day: sidereal.—The interval of *time* from a *transit* of the (true) *vernal equinox* across a given *meridian* to its next successive *transit* across the same *meridian.*

The length of the sidereal day is subject to slight irregularities on account of small differences between the positions of the true *equinox,* which is affected by *precession* and *nutation,* and the mean *equinox,* which is affected by *precession* but not by *nutation.* See *time: sidereal; equinox: vernal.*

day: solar.—The interval of *time* from the *transit* of either the sun or the *mean sun* across a given *meridian* to the next successive *transit* of the same body across the same *meridian.* See *day: apparent solar; day: mean solar.*

The term *day* is frequently used in connection with a particular period in one of the longer scales, as "day of month"; in most cases, the term date is preferred.

daylight-saving time.—See under *time.*

Decca.—A continuous wave electronic navigation system for measuring distance differences with respect to fixed transmitters of known position.

A ship or aircraft starting from a known point makes use of two receivers which indicate the number of nodes encountered as it moves through the fixed phase patterns of two pairs of synchronized transmitters. The phase readings are plotted on a Decca chart containing hyperbolic lines of position.

declination (astronomy).—The *angle* at the center of the celestial *sphere* between the radius passing through a celestial body and the plane of the *celestial equator.*

Declination (astronomy) is measured by the *arc* of the *hour circle* between the celestial body and the *equator;* it is plus when the body is north of the *equator,* and minus when south of it. It corresponds to *latitude* on the earth, and with *right ascension* forms a pair of *coordinates* which defines the position of a body on the *celestial sphere.*

declination: magnetic.—See under *magnetic declination.*

declination: parallel of.—A small circle on the *celestial sphere* parallel to the *celestial equator.*

declination arc (solar compass).—A graduated *arc* on a surveyor's *solar compass* or on the *solar attachment* of an engineer's *transit,* on which the *declination* of the sun (corrected for *refraction*) is set off.

This represents one side (*polar distance*) of the *astronomical triangle,* which is solved mechanically by means of the *solar compass* or *attachment.*

declination arc (surveyor's compass).—A graduated *arc* attached to the *alidade* of a *surveyor's compass* or *transit,* on which the *magnetic declination* is set off.

When the *magnetic declination* is set off on the declination arc of a *surveyor's compass* or *transit,* a reading of the needle will give a bearing corrected for that *declination.*

declination vernier.—The *vernier* used in reading the *declination arc* on a *solar compass* or *attachment,* or the *magnetic declination* on a *surveyor's compass* or *transit.*

deflection angle.—See under *angle.*

deflection anomaly.—See under *anomaly.*

deflection of the plumb line.—The *angle* at a point on the earth (*geoid*) between the *vertical* (direction of the plumb line) and the direction of the *normal* to the *spheroid of reference* through the point. Also called deflection of the vertical or station error.

It is also equal to the *angle* between the tangents to the *geoid* and the *spheroid;* and equivalent to the *topographic deflection* corrected for the effects of *isostasy.*

deflection of the vertical.—See under *deflection of the plumb line.*

degree of curve.—See under *curve.*

dep.—The usual abbreviation for *departure* (*plane surveying*).

departure (plane surveying).—The *orthographic projection* of a line on an east-west axis of reference.

The departure (dep.) of a line is the difference of the *meridian distances* or *longitudes* of the ends of the line. It is east or positive, and sometimes called the easting, for a line whose *azimuth* or *bearing* is in the northeast or southeast quadrant; it is west or negative, and sometimes called the westing, for a line whose *azimuth* or *bearing* is in the southwest or northwest quadrant. Departure is also a term used in navigation.

depression contour.—See under *contour.*

depth of isostatic compensation.—See under *isostatic compensation.*

desk outline.*—An *outline map* of sufficiently *small scale* to be suitable for use at a desk.

This term is not recommended for use.

detail: junction.—A sketch or working diagram showing the details of the various levelings at a junction.

detailed surveys and maps.—See under *surveys and maps.*

diaphragm (surveying).—The thin glass disk on which etched lines forming a *reticle* are placed.

difference of latitude (plane surveying).—See under *latitude.*

dip of horizon.—See under *horizon.*

direct angle.—See under *angle to right.*

direct leveling.—See under *leveling.*

direct observation.—See under *observation.*

direction.—In surveying and mapping, the *angle* between a line or plane and an arbitrarily chosen reference line or plane.

At a *triangulation station,* observed *horizontal angles* are reduced to a common initial, and termed *horizontal directions.* They are usually collected into a single list of directions, with the direction of 0° placed first, and the other directions arranged and increasing in clockwise order.

direction instrument.—See under *theodolite.*

direction method, determination of astronomic azimuth.—See under *azimuth.*

direction method of adjustment (triangulation and traverse).—See under *adjustment.*

direction of gravity.—See under *gravity.*

discrepancy.—A difference between results of duplicate or comparable measures of a quantity. The difference in computed values of a quantity obtained by different processes using data from the same *survey.*

Examples: The difference in the length of two measures of the same line. The amount by which the values of a *position* of the third point of a triangle as computed from the two other points may fail to agree, when the triangle has not been corrected for closure. Discrepancy is closely associated with, but not identical with, *closure.* See *discrepancy: accumulated.*

discrepancy: accumulated.—The sum of the separate *discrepancies* which occur in the various steps of making a survey or of the computation of a *survey.*

Example: If two independently run lines of leveling over the same series of *bench marks* are computed separately, differences or *discrepancies* between the two sets of values of *elevations* will accumulate. This does not mean that the accumulated *discrepancy* will necessarily increase in magnitude.

dispersion; dispersive power.—See under *refraction: index of refraction.*

distance angle.—See under *angle.*

distribution map.—See under *map.*

diurnal aberration.—See under *aberration of light* (*astronomy*).

diurnal parallax.—See under *parallax.*

diurnal variation.—That component of a determinable magnitude which passes through a complete cycle in one day.

Such a component is said to have a periodicity of one day. Example: the diurnal variation of *magnetic declination.*

divergence (leveling).—The difference between the numerical values of two *runnings* over the same *section* of a *line of levels.* Divergence and "partial" are practically the same thing.

divergence: accumulated (leveling).—The algebraic sum of the *divergences* or "partials" for the *sections* of a *line of levels,* from the beginning of the line to any section end at which it is desired to compute the total divergence.

division; graduation.—The placing of marks on an instrument or device to represent *standard* values thereon. Also, the marks so placed.

The term division is applied especially to a circle, the value of a complete circle being absolute, that is, not depending upon an adopted *standard.* Graduation is more often applied to the placing of intermediate marks on an instrument or device (tape, thermometer) where interpolation is made between marks which represent conventional or standard values. However, no exact distinction is made between the two terms, division and graduation, as generally used. See *calibration; standardization.*

Doolittle Method.—A modification of Gauss' method of solving *normal equations.*

The Doolittle Method, with further modifications made in recent years, is used in the adjustment of survey data by members of the U. S. Coast and Geodetic Survey. It is named for M. H. Doolittle, for many years a member of the Computing Division of that Bureau, and author of a description and explanation of the method which appeared in the U. S. Coast and Geodetic Survey Report for 1878, pages 115–118.

double dating.—Dating an event according to both the *Julian* and the *Gregorian Calendars.*

In Great Britain and her colonies, the *Julian Calendar,* with March 25 as the beginning of the year, was officially replaced in 1752 by the *Gregorian Calendar,* with January 1 as the beginning of the year. The difference between the two calendars having increased from 10 days in 1582 to 11 days, the change was made by having September 2, 1752, followed immediately by September 14. To avoid confusion resulting from the change, dates according to the *Julian Calendar* were marked "old style" or "(O. S.)"; those on the *Gregorian Calendar,* "new style" or "(N. S.)". In double dating early American records, not only the day and the month, but also the year, are subject to change. In England, at the time of the change, the official year commenced on March 25, so that March 24, 1730 (O. S.) corresponded to April 4, 1731 (N. S.), but the next day was March 25, 1731 (O. S.) or April 5, 1731 (N. S.). This practice was not universal, for there was some popular use of January 1 as the beginning of the year.

double meridian distance.—See under *meridian distance.*

double zenith distance.—See under *zenith distance.*

doubly azimuthal map projection.—See under *map projection.*

draconitic (nodical) month.—See under *month.*

drag (theodolite).—A slight movement of the graduated circle of a *theodolite* produced by the *rotation* of the *alidade.*

Drag may be due to excessive friction in the instrument *centers,* to undue *tolerance* in the fit of the *centers,* or to instability in the instrument supports.

dummy pendulum.—See under *pendulum.*

dumpy level.—See under *leveling instrument.*

duplex base-line measuring apparatus.—See under *base apparatus.*

duplicate level line.—See under *level line.*

dynamic correction.—The quantity that must be added to the *orthometric elevation* of a point to obtain its *dynamic number.*

dynamic map.—See under *map.*

dynamic number.—The work required to raise a unit mass from *sea level* to a given point, expressed in *absolute units.*

For all points in a given *level surface* the dynamic number is the same, and is not very different from the height (in the unit chosen) of any point in the surface. In the metric system, the dynamic number of a point is the work required to raise a mass of 1 kilogram against the force of *gravity* from *sea level* to the *level surface* passing through the point, the work being measured in standard kilogram-meters at *sea level* in latitude 45°. In the English system, the pound and standard foot-pound are employed instead of the *meter* and standard kilogram-meter.

dynamic temperature correction (pendulum).—The *correction* to the observed period of a *pendulum* for the rate of change of its temperature.

The dynamic temperature correction is definitely related to the type of pendulum apparatus used, and is dependent especially on the mounting of the thermometer and the shape of the *pendulum.* It may vary not only in magnitude but may even change sign when the type of apparatus is changed.

dyne.—A force which, acting on a mass of one gram, imparts to that mass an *acceleration* of one centimeter per second per second. See *gal.*

The dyne is the unit of force of the *c. g. s. system* of units. Until about 1930, the dyne was used by the U. S. Coast and Geodetic Survey in stating values of gravity. Since that time, *gravity* has been reported in terms of the *gal,* the c. g. s. unit of *acceleration.*

E

easement curve.—See under *curve.*

easting.—See under *departure (plane surveying).*

eccentric object observed.—See under *eccentric signal.*

eccentric reduction (triangulation).—The *correction* which must be applied to an observed *direction* made with instrument or signal, or both, eccentric, to reduce the *observed value* to what it would have been if there had been no *eccentricity.*

eccentric signal.—A signal (target) which is not in the same vertical line with the *station* which it represents.

An observed *direction* to an eccentric signal is reduced by the application of a computed *correction* to what it would be if the signal were in the same vertical line with the station center which it represents. See *center: reduction to center.* The eccentric signal is known as the eccentric object observed.

eccentric station.—A *survey* point over which an instrument is centered and observations made, and which is not in the same vertical line with the *station* which it represents and to which the observations will be reduced before being combined with observations at other *stations.*

In general, an eccentric station is established and occupied when it is impracticable to occupy the station center, or when it becomes necessary in order to see points which are not visible from the station center. As the data resulting from the occupation of an eccentric station are referred to the station center, which should be marked with a permanent *monument,* the mark at an eccentric station is usually of a temporary character. See *center: reduction to center.*

eccentricity.—Amount of deviation from a center.

See *eccentricity of instrument; eccentric station; eccentricity of alidade.*

eccentricity (surveyor's compass).—An effect due to one or a combination of the following conditions: a straight line through the ends of the magnetic needle fails to pass through the center of *rotation* of the needle; the center of *rotation* of the needle is not coincident with the center of figure of the graduated circle; the *line of sight* fails to pass through the vertical axis of the instrument.

eccentricity of alidade.—The distance between the center of figure of the index points on an *alidade* and the center of figure of the graduated circle.

The index points (of *vernier* or *micrometer microscope*) are carried by the *alidade,* and any eccentricity of alidade combines with *eccentricity of circle* to form *eccentricity of instrument.*

eccentricity of circle.—The distance between the center of figure of a graduated circle and its center of *rotation.*

Eccentricity of circle is usually expressed in terms of its equivalence in seconds of *arc* on the circle. It may be made quite small by instrument-shop adjustment. Its effect on an observed *direction* is eliminated by reading the circle at equidistant points around its circumference. See *eccentricity of instrument.*

eccentricity of ellipse.—The ratio of the distance between the center and a focus of an ellipse to the length of its semi-major axis.

The semi-major and semi-minor axes are represented by a and b, respectively, and the eccentricity by e, then

$$e=\sqrt{\frac{a^2-b^2}{a^2}}.$$

eccentricity of instrument.—The combination: *eccentricity of circle* and *eccentricity of alidade.*

The effect of eccentricity of instrument on an observed *direction* is eliminated by having the *verniers* or *micrometer microscopes* with which the circle is read spaced at equal distances around the circle.

eccentricity of spheroid of revolution.—The *eccentricity of an ellipse* forming a meridional section of the *spheroid.*

eclipse.—1. The reduction in visibility or disappearance of a non-luminous body by passing into the shadow cast by another non-luminous body. 2. The apparent cutting off, wholly or partially, of the light from a luminous body by a dark body coming between it and the observer.

1. The first type of eclipse is exemplified by a lunar eclipse, the moon passing through the shadow cast by the earth; or by the passage of a satellite into the shadow cast by its planet; but when the satellite actually passes directly behind its planet, it may properly be termed an *occultation.*

2. The second type of eclipse is exemplified by a solar eclipse, caused by the moon passing between the sun and the earth. If the relative positions and distances are such that at a point on the earth the sun is completely obscured, the eclipse is total; if the distances are such that when in line with the sun, the moon is surrounded by a ring of light, the eclipse is annular; and when the moon passes to one side of a straight line from sun to observer, and shows a crescent of light, it is a partial eclipse.

ecliptic.—The *great circle* of the *celestial sphere* traced by the plane of the earth's orbit (path of center of gravity of earth-moon system).

The ecliptic represents very closely, but not exactly, the apparent path of the sun in the sky. The points in which the ecliptic intersects the *celestial equator* are the *equinoxes,* and the *angle* of intersection is the *obliquity of the ecliptic.*

ecliptic: obliquity of the.—The acute *angle* of intersection between the *ecliptic* and the *celestial equator.*

The obliquity of the ecliptic is slightly less than 23½° and is decreasing at the rate of about ½″ per year.

Egault level.—See under *leveling instrument.*

elevation.—The vertical distance of a point above or below a reference surface or *datum.*

In the fundamental horizontal *control survey* of this country, the *datum* for elevations is *mean sea level.*

elevation: adjusted.—The *elevation* resulting from the application of an *adjustment correction* to an *orthometric elevation.* Also the *elevation* resulting from the application of both an *orthometric correction* and an *adjustment correction* to a *preliminary elevation.*

elevation: field.—An *elevation* taken from the field computation of a *line of levels.*

elevation: fixed.—An *elevation* which has been adopted, either as a result of tide observations or previous adjustment of spirit leveling, and which is held at its accepted value in any subsequent *adjustment.*

elevation: orthometric.—A *preliminary elevation* to which the *orthometric correction* has been applied.

elevation: preliminary.—An elevation arrived at in the office after the *index, level, rod,* and *temperature corrections* have been applied to the observed differences of elevation and new *elevations* have been computed.

elevation: standard.—An *adjusted elevation* based on the Sea Level Datum of 1929.

ellipse: eccentricity of.—See under *eccentricity of ellipse.*

ellipse: ellipticity of.—See under *ellipticity of ellipse.*

ellipsoid.—See under *spheroid.*

ellipsoid: triaxial.—An *ellipsoid* having three unequal axes, the shortest being its polar axis, while the two longer ones lie in the plane of its *equator.* See *gravity formula, longitude term.*

elliptic arc: plane.—See *plane elliptic arc.*

ellipticity of an ellipse.—The ratio between the difference in length of the semi-axes of an ellipse and its semi-major axis.

The semi-major and semi-minor axes are represented by a and b, respectively, and the ellipticity by ϵ, then $\epsilon = \frac{a-b}{a}$. The *ellipticity of the spheroid,* referring to the earth, is called the *flattening of the earth,* or its *compression,* and is also represented by f.

ellipticity of the spheroid.—See under *flattening of the earth.*

engineering map.—See under *map.*

engineering survey.—See under *survey.*

ephemeris.—A statement presenting positions and related data for a celestial body for given epochs (dates) at uniform intervals of *time.* Also a publication containing such data for a number of celestial bodies.

Such a publication is the American Ephemeris and Nautical Almanac: this contains for specified instants of *time* the numerical values of *coordinates* of the principal celestial bodies referred to circles whose positions are independent of the diurnal *rotation* of the earth; also the elements of the positions of the reference circles, and numbers used in computing the effects upon those *coordinates* of changes in the *position* of an observer; and in general, all those phenomena relating to the heavenly bodies which may be regarded as functions of *time.* While custom has approved the use of the singular form, ephemeris, to designate a publication containing data relating to a number of celestial bodies, where specific mention is made of those bodies, the plural form, ephemerides, is used; for example, the ephemerides of the planets. For a single body, the singular form is used: for example, the ephemeris of the sun.

equal-area (authalic) latitude.—See under *latitude.*

equal-area map projection.—See under *map projection.*

equation: angle.—A *condition equation* which expresses the relationship between the sum of the measured *angles* of a closed figure and the theoretical value of that sum, the unknowns being the *corrections* to the observed *directions* or *angles,* depending upon which are used in the *adjustment.*

Sometimes called a triangle equation, an angle equation is used to make the sum of the three observed *angles* of a triangle, with *corrections* applied, equal to 180° plus the *spherical excess* of the triangle.

equation: azimuth.—A *condition equation* which expresses the relationship between the fixed azimuths of two lines which are connected by triangulation or *traverse.*

When a *survey* (*triangulation* or *traverse*) connects two lines whose *azimuths* are fixed by direct observation or by previous *surveys,* an azimuth equation is used to make the *azimuth* of either line as computed through the adjusted *survey* from the other line agree with its *azimuth* as previously fixed.

equation: condition.—An equation which expresses exactly certain relationships that must exist among related quantities, which are not independent of one another, exist a priori, and are separate from relationships demanded by observation.

Example: in measuring the *angles* of a triangle, no condition exists until all three *angles* are measured. The condition equation will then express the condition that the three measured *angles* plus certain *corrections* must equal 180° plus the *spherical excess* of the triangle. The various condition equations set up in *survey* work are defined under terms which are descriptive of the conditions: as, *angle equation, side equation, length equation, latitude equation, longitude equation, azimuth equation.*

equation: correlate.—An equation derived from an *observation* or *condition equation,* employing undetermined multipliers, and expressing the condition that the sum of the squares of the *residuals* (or *corrections*) resulting from the application of these multipliers to the *observation* or *condition equations* shall be a minimum.

In the *least-squares* adjustment of *triangulation,* correlate equations are formed directly from the *observation* or *condition equations,* there being as many correlate equations as there are *corrections* to be determined, but only as many undetermined multipliers (correlates or correlatives) as there are *observation* or *condition equations.* From these correlate equations, the *normal equations* are formed, equal in number to the undetermined multipliers which constitute the unknowns in the *normal equations.* The solution of the *normal equations* determines values for the multipliers which, when substituted in the correlate equations, give values for the corrections which will satisfy the *observation* or *condition equations,* make the observations and their functions consistent among themselves, and at the same time make the adjusted values the most probable that can be derived from the given observations.

equation: error.—The probability equation which expresses the laws of the occurrence of *accidental errors.*

The error equation is the basis of the method of *least squares,* used in the *adjustment of observations* for determining the *most probable value* of a result from those observations.

equation: Laplace.—See under *Laplace equation.*

equation: latitude.—A *condition equation* which expresses the relationship between the fixed *latitudes* of two points which are connected by *triangulation* or *traverse.*

When a *survey* (*triangulation* or *traverse*) connects two points whose *latitudes* have been fixed by direct observation or by previous *surveys,* a latitude equation is used to make the *latitude* of either point as computed through the *survey* from the other point agree with its *latitude* as previously fixed.

equation: length.—A *condition equation* which expresses the relationship between the fixed lengths of two lines which are connected by *triangulation.*

When a section of *triangulation* connects two lines whose lengths are fixed by direct measurement or by previous *triangulation,* a length equation is used to make the length of either line as computed through the adjusted *triangulation* from the other line agree with its length as previously fixed.

equation: longitude.—A *condition equation* which expresses the relationship between the fixed *longitudes* of two points which are connected by *triangulation* or *traverse.*

When a *survey* (*triangulation* or *traverse*) connects two points whose *longitudes* have been fixed by direct observation or by previous *surveys,* a longitude equation is used to make the *longitude* of either point as computed through the *survey* from the other point agree with its *longitude* as previously fixed.

equation: normal.—An equation derived from *observation* or *condition equations* or from *correlate equations,* expressing the condition that the sum of the squares of the *residuals* (or *corrections*) resulting from the substitution in the *observation* or *condition equations* of factors obtained from the normal equations either directly or through the *correlate equations* shall be a minimum.

In a *least-squares* adjustment, *corrections* are desired to observed values which are connected together by a series of *observation* or *condition equations,* the number of such equations being smaller than the number of observed values on which they depend. The basic equations are transformed into normal equations, either directly or through the medium of *correlate equations,* which express the condition stated above and which contain the same number of unknowns as there are equations. Factors obtained from the solution of normal equations, either directly or through the *correlate equations,* are applied to the *observation* or *condition equations* to obtain the desired *corrections.*

equation: observation.—A *condition equation* which connects interrelated unknowns by means of an observed function.

Example: An *angle equation:* the unknowns are the *corrections* to the *observed angles;* the function is the sum of those *observed angles* expressed as a *closing error.*

Alternate definition: A *condition equation* connecting the function observed and the unknown quantity whose value is sought.

equation: perpendicular (traverse).—A *condition equation* to reduce to zero the algebraic sum of the *projections* of the separate lines of a *traverse* upon perpendiculars to a fixed line with which the *traverse* forms a closed figure.

The perpendicular equation and the *azimuth equation* together provide for the removal of *errors of closure* of a *traverse* which forms a loop with some fixed line such as a line of adjusted *triangulation,* by determining *corrections* to the *observed angles* of the *traverse.* The *projections* of the lines of the *traverse* upon lines which are perpendicular to a fixed line correspond to *departures* of those lines when the fixed line is considered the *meridian* of reference.

equation: side.—A *condition equation* which expresses the relationship between the various sides in a *triangulation* figure as they may be derived by computation from one another.

A side equation is used to make the computed length of a triangle side the same for all routes through the *triangulation* whereby it may be derived.

equation of time.—See under *time.*

equator: astronomic.—The line on the surface of the earth whose *astronomic latitude* at every point is 0°. Also termed the terrestrial equator.

Due to the *deflection of the plumb line,* the astronomic equator is not a plane curve. However, the *verticals* at all points on it are parallel to one and the same plane, the plane of the *celestial equator;* that is, the *zenith* at every point on the astronomic equator lies in the celestial equator.

equator: celestial.—The *great circle* on the *celestial sphere* whose plane is perpendicular to the axis of *rotation* of the earth.

In astronomic work, because parallel lines meet at infinity, the plane of the celestial equator is sometimes assumed to pass through the point of observation.

equator: geodetic.—The circle on the *spheroid* midway between its poles of *revolution.*

The geodetic equator is the line of 0° *geodetic latitude,* from which *geodetic latitudes* are reckoned, north and south, to 90° at the poles. The plane of the geodetic equator cuts the *celestial sphere* in a line coinciding with the *celestial equator,* because the axis of the *spheroid* of reference is by definition parallel to the axis of rotation of the earth.

equator: terrestrial.—See under *equator: astronomic equator.*

equatorial horizontal parallax.—See under *parallax: diurnal parallax.*

equatorial intervals.—The *angles,* expressed in units of *time,* between the various lines which compose the *reticle* of an astronomical *transit* and the mean position of those lines.

The equatorial interval for a given line of a *reticle* is equal to the time interval required for the image of a star on the *equator* (*declination,* 0°) to travel from the line in question to the mean line of the *reticle,* or from the mean line to the line in question, the instrument being adjusted in the *meridian.* In *time* determinations with an *astronomical transit,* equatorial intervals are used in reducing incomplete observations to a mean value.

equiangular spiral.—See under *rhumb line.*

equiangulator.—An *astrolabe.*

equinoctial colure.—See under *colure.*

equinox.—A point of intersection of the *celestial equator* and the *ecliptic.*

There are two equinoxes: the *vernal equinox,* apparently traversed by the sun at the beginning of spring; and the *autumnal equinox,* apparently traversed by the sun at the beginning of autumn.

equinox: autumnal.—The point of intersection of the *celestial equator* and the *ecliptic,* apparently traversed by the sun in passing from north to south.

equinox: vernal.—The point of intersection of the *celestial equator* and the *ecliptic,* apparently traversed by the sun in passing from south to north.

The vernal equinox is also called the "first point of Aries" and "first of Aries." It is the point from which *right ascension* is reckoned along the *celestial equator* and *celestial longitude* along the *ecliptic.* The position of the true *equinox* is affected by *precession* and *nutation,* while the position of the mean *equinox* is affected by *precession* but not by *nutation.* See *day: sidereal; time: sidereal.*

equipotential surface (geodesy).—A surface having the same potential of *gravity* at every point.

Having the same potential of *gravity* at every point, no work is done when a body is moved about in such a surface. When bodies of the same mass are moved from one equipotential surface to another, the same amount of energy is developed or expended, accordingly as the bodies are lowered or raised, and regardless of the route followed. In lifting a unit mass from *sea level* to any other specified equipotential surface, the amount of work required is the same at the *equator* as at the poles: at the *equator* the height of any equipotential surface above *sea level* is greater and the force of gravity at that surface less than for the same equipotential surface at the poles. An equipotential surface is a *level surface.* A particular equipotential surface is identified by its *dynamic number.*

equivalent map projection.—See under *map projection: equal-area map projection.*

error (general).—The difference between an observed or calculated value of a quantity and the ideal or true value of that quantity.

Since the ideal or true value of a quantity, with few exceptions (see below), cannot be known with exactness, the term error is applied to a difference between an observed or calculated value of a quantity and some value determined by established procedure and used in lieu of the ideal or true value. Exceptions: the ideal or true value of a quantity can be known with exactness when it is (a) mathematically determinable, independent of observation, as for example, the sum of the three angles of a plane triangle is 180°; and (b) when it is a conventional value established by authority, as for example, the length of the *meter* (unit) defined by the *International Prototype Meter* at the International Bureau of Weights and Measures. Errors are of various kinds, depending upon how and where they originate. The term error with appropriate adjective or qualifying clause is used to designate the kind of error: as, *accidental error, error of observation,* etc.

error: accidental.—An error, sometimes designated as an irregular *error,* produced by irregular causes whose effects upon individual observations are governed by no fixed law connecting them with circumstances and which therefore can never be subjected to a priori computation.

Theoretically, an accidental error is composed of an infinite number of independent infinitesimal *errors,* all of equal magnitude, each as likely to be positive as negative. In practice, an accidental error is composed of an indefinitely large number of elemental *errors,* each as apt to be positive as negative.

It is upon the probabilities expressed in the above definition that the principle of *least squares* is based; and it is to the elimination of accidental errors only that *least squares* may properly be applied.

error: average.—The mean of all the *errors* taken without regard to sign.

Average error is sometimes defined as the mean without regard to sign of the mean of the plus *errors* and the mean of the minus *errors.* Since there will be about the same number of plus *errors* as of minus *errors* in a well-balanced series of observations, the two methods of obtaining the average error will give practically the same result. In computing the average error, the *residual errors* (residuals) are used.

error: clamping.—A *systematic error* in observations made with a *repeating theodolite* due to strains set up by the clamping devices of the instrument.

error: constant.—A *systematic error* which is the same in both magnitude and sign through a given series of observations.

Constant errors are sometimes considered as forming a class distinct from *systematic errors,* but the distinction is unimportant, and in practice constant errors are treated as a type of *systematic error.* A constant error tends to have the same effect upon all the observations of the series or portion thereof under consideration, and therefore does not usually have any influence on the computed *probable error* of the series. An example of a constant error is the index error of a *precision* instrument.

error: external.—See under *error: theoretical* (or *external*) *error.*

error: instrumental.—A *systematic error* arising from imperfect condition of the instrument used.

Instrumental errors may arise from conditions that are constant with an instrument, as *errors* of graduation of a circle; or they may arise from lack of complete adjustment of some part of the instrument, as the *error of collimation.* Instrumental errors are susceptible of laboratory determination; they may be eliminated from a result by a suitable program of field procedure.

error: mean.—See under *error: mean-square error.*

The use of mean error should be avoided because of possible confusion with *average error,* which has a different meaning.

error: mean of the errors.—See under *error: average error.*

The use of mean of the errors should be avoided because of possible confusion with *mean error,* which has a different meaning.

error: mean-square.—The quantity whose square is equal to the sum of the squares of the individual *errors* divided by the number of those *errors.*

In the computation of the mean-square error from observations of unequal weight, account must be taken of the *weights.* In practice, *residual errors* are used in determining a mean-square error. The use of *mean error,* in place of mean-square error, should be avoided, because of possible confusion with *average error* which has a different meaning.

error: parallactic.—An *error* due to *personal* or *instrumental parallax.*

error: personal.—A *systematic error* caused by an observer's personal habits in making observations, or due to his tendency to react mentally and physically in the same way under similar conditions.

A *systematic error* arising from personal habits of an observer, such as standing in the same position relative to the end of a tape when measuring the length of a line, may be eliminated from a result by an observing program (shift of position) which makes the *error* positive for half of the observations and negative for the remainder of the observations. See *parallax: instrumental.*

A *systematic error* arising from the mental or motor reaction of an observer to the sensory perception of a phenomenon may be eliminated from a result either by an observing program which neutralizes positive values with negative values, or by determining the size and sign of the *error* by some mechanical means. In the determination of *time,* the personal error is termed *personal equation.*

error: probable.—A quantity of such size that the probability of the occurrence of an *error* larger than that quantity is the same as the probability of the occurrence of an *error* of lesser magnitude.

If the *errors* in a series of observations be arranged in order of magnitude without regard to sign, and if the series be indefinitely large, the probable error will fit the middle place in that list of errors.

Expressed in another way, the probable error of a result is a quantity such that the probability that a second determination obtained under the same conditions as the first will differ from the first determination by less than the probable error is the same as the probability that such difference will be greater than the probable error.

The probable error of the result of a series of observations is a function of the *accidental errors* attending the individual observations of the series. A *systematic error* may often remain in the series with little effect on the size of the probable error. Probable error does not mean an *error* that is more apt to occur than an *error* of any other size. Theoretically, a probable error is derived from the *errors* in an indefinitely large series of observations; in practice, a probable error is calculated from the *residual errors* in a series of limited length. Probable errors are useful in comparing the *accuracy* of similar observations, and serve as criteria in prescribing degrees of *accuracy* and *precision* to be attained.

error: residual.—The difference between any value of a quantity in a series of observations, corrected for known *systematic errors,* and the value of the quantity obtained from the combination or adjustment of that series.

Residual errors correspond to the *corrections* obtained in a *least-squares* adjustment. They are sometimes called simply *errors,* and sometimes residuals. The latter term is generally used in referring to actual values in a specific computation. In practice, it is the residual errors which enter into a computation of *probable error.*

error: systematic.—An *error* whose algebraic sign and, to some extent, magnitude bear a fixed relation to some condition or set of conditions.

In its broadest sense, the term systematic error includes *constant errors.* Under similar conditions, systematic errors tend to be repeated; if the conditions do not change, the *error* will be constant. The inclusive definition is preferred.

Systematic errors are regular, and therefore are subject to a priori determination. They are generally eliminated from a series of observations by a suitable observing program or by computation, before the application of *least-squares* for the elimination or reduction of *accidental errors.* Systematic errors are divided into *theoretical* or *external errors, instrumental errors,* and *personal errors,* according to their origin and nature.

error: theoretical (or external).—A *systematic error* arising from natural physical conditions, outside the observer.

Theoretical errors are exemplified by the effect of *atmospheric refraction* in *spirit leveling;* by the changes in the length of a tape due to its thermal expansion; by the effects of atmospheric pressure on *elevations* determined with a *barometer.* Theoretical errors may be controlled to some extent by making observations only when natural conditions are favorable, as measuring the length of a line with a steel tape at night or in cloudy weather.

Theoretical errors are determined by means of formulas and observed data obtained especially for the purpose, as determining the length of a metal tape by suitable formula using the *coefficient of thermal expansion* and the observed temperature of the tape.

error: true.—See under *error (general).*

True error corresponds to *error (general)* defined above; its use should be avoided.

error equation.—See under *equation.*

error of closure.—The amount by which a value of a quantity obtained by *surveying* operations fails to agree with another value of the same quantity held fixed from earlier determinations or with a theoretical value of the quantity.

See *error of closure, traverse; error of closure, triangle; error of closure, levels; error of closure, horizon.*

error of closure, angles.—The amount by which the actual sum of a series of *angles* fails to equal the theoretically exact value of that sum. See *error of closure of horizon; error of closure of triangle.*

error of closure in azimuth.—The amount by which two values of the *azimuth* of a line, derived by different *surveys* or along different routes, fail to be exactly equal to each other.

Generally, one value is derived by computations carried through the *survey* (*triangulation* or *traverse*) ; the other is an *adjusted* or fixed value determined by an earlier or a more *precise survey,* or by independent *astronomical* observations.

error of closure in leveling.—The amount by which two values of the *elevation* of the same *bench mark,* derived by different *surveys* or through different *survey* routes or by independent observations, fail to be exactly equal to each other.

The closure may be developed in a line of *leveling* which starts and ends on different *bench marks* whose *elevations* are held fixed; or it may start and close on the same *bench mark.*

error of closure of horizon.—The amount by which the sum of a series of *horizontal angles* measured between adjacent lines in a complete circuit of the *horizon* fails to equal exactly 360°. See *horizon: closing the horizon.*

error of closure of triangle.—The amount by which the sum of the three *observed angles* of a triangle fails to equal exactly 180° plus the *spherical excess* of the triangle. See *equation: angle equation.*

error of closure, traverse.—The amount by which a value of the *position* of a traverse station as obtained by computation through a *traverse* fails to agree with another value of the same station as determined by a different set of observations or route of *survey.*

The *traverse* may run between two stations whose *positions* are held fixed, or it may start from and end on the same station. In either case there are two values for the *position* of the final station; one known before the *traverse* was computed, the other obtained by computations carried through the *traverse;* the difference between these is the *error of closure.* It may be resolved into closure in latitude, and closure in longitude (or departure). The total closure is also spoken of as closure in position.

error of collimation.—See under *collimation.*

error of observation.—The difference between an observed value of a quantity and a value adopted as representing the ideal or true value of that quantity.

Errors of observation are composed of either one or both of two general classes of *error; accidental errors* and *systematic errors.* Sometimes *constant errors* are considered as forming a third class, but more often these are treated as belonging with the *systematic errors.* Errors of observation are also classified for study according to their origin, as *theoretical errors* or *external errors, instrumental errors,* and *personal errors.* The algebraic sign of an error of observation is determined from the equation: error=observed value−adopted ideal value.

The sign of the *error* is opposite that of the corresponding *correction.*

existent corner (United States public-land surveys).—See under *corner.*

explement of angle.—See under *angle.*

exploratory survey.—See under *survey.*

exterior angle.—See under *angle.*

extra foresight.—See under *foresight.*

eyepiece micrometer.—See under *micrometer: ocular.*

F

factor: conversion.—That factor by which the numerical value of a measurement made in one system of units must be multiplied to arrive at the numerical value of the same measurement in another system of units.

Fahrenheit scale.—A temperature scale in which 32° marks the freezing point and 212° the boiling point of water at 760 mm. barometric pressure.

falling (United States public-land surveys).*—The distance, measured along an established line from its intersection with a *random line,* to a *corner* on which the *random line* was intended to close.

fathometer.—An echo-sounding instrument used for depth measurements in water.

For descriptions of several types of fathometers, see U. S. Coast and Geodetic Survey Special Publication No. 143, Hydrographic Manual.

fiducial mark.—An index line or point. A line or point used as a basis of reference.

field elevation.—See under *elevation.*

field position.—See under *position.*

figure of the earth.—See under *geoid, spheroid.*

finder circle.—A small *vertical circle* with coarse *graduations* and accessory *spirit level* of low sensitivity attached to an astronomical *telescope* in a plane perpendicular to its *horizontal axis,* and used in placing the *telescope* in approximate position for observing.

With a computed *altitude* at the proposed time of observation, the *telescope* is pointed in the direction of the object to be observed; when that object comes into the field of view, the finder circle will have served its purpose, and the observations will be made with the more precise apparatus provided for the purpose.

finder telescope.—A small *telescope* of low power and wide angular field of view, attached to and parallel with a larger *telescope* of much higher power and very restricted field of view, and used in pointing the larger *telescope* at a celestial object.

The finder telescope serves as a sighting device; a celestial object is easily sighted in the finder telescope, and brought to the center of its *reticle,* when it will be visible in the large *telescope* also.

first-order bench mark.—See under *bench mark.*

first-order control surveys.—See under *first-order work (control surveys).*

first-order level.—See under *leveling instrument.*

first-order leveling.—See under *leveling.*

first-order traverse.—See under *traverse.*

first-order triangulation.—See under *triangulation.*

first-order work (control surveys).—The designation given *survey* work of the highest prescribed order of *precision* and *accuracy.*

Such *surveys* were formerly called primary; in 1921, representatives of the various Federal map-making and map-using organizations changed the designation to *precise;* and in 1925, the Federal Board of Surveys and Maps adopted the present designation (first-order), and established *standards* for it by prescribing criteria for acceptable work. See under *triangulation; leveling.*

Fischer level.—See under *leveling instrument*.

fix.—The position on a *map* of a point of observation obtained by *surveying* processes. Also, the act of determining such a *position*.

fixed elevation.—See under *elevation* and also *position: adjusted*.

fixed position.—See under *position: adjusted*.

flare triangulation.—See *triangulation: flare*.

flash apparatus.—An auxiliary apparatus used in timing a *pendulum* during observations for *intensity of gravity*.

The flash apparatus used in *pendulum* observations is composed of a *telescope* for observing, an electric light for illumination, and an electro-magnet which is operated by a break-circuit *chronometer* and which controls a system of shutters admitting periodic flashes of light into the *receiver* and onto the mirror of the *pendulum* whence they are reflected back into the *telescope*, and coincidences between *pendulum* and *chronometer* observed.

flattening (of the earth).—The ratio of the difference between the equatorial and polar radii of the earth (major and minor semi-axes of the *spheroid*) and its equatorial radius (major semi-axis).

The flattening of the earth is the *ellipticity* of the *spheroid* and equals the *ellipticity of an ellipse* forming a meridional section of the *spheroid*. If a and b represent the major and minor semi-axes of the spheroid, and f is the flattening of the earth,

$$f=\frac{a-b}{a}.$$

The magnitude of the flattening is sometimes expressed by stating the numerical value of the reciprocal of the flattening, $\frac{a}{a-b}$. The flattening of the earth is also termed its compression.

flexure (pendulum).—The bending of a swinging *pendulum*, due to its lack of perfect rigidity.

The effect of the bending of a swinging *pendulum* due to its lack of perfect rigidity is to increase the period of vibration; that is, the flexible *pendulum* swings less rapidly than the rigid *pendulum*. The effect may be regarded either as due to the change in the moment arm of the various parts of the *pendulum* as it bends, or to energy storage in the bent *pendulum*.

The effect of the bending is to increase the period of vibration in both positions of the reversible *pendulum*. The sign of the resulting correction depends upon the exact geometrical construction of the *pendulum*. In relative determinations of gravity, account is not taken of the bending of the *pendulum*, but the term flexure is applied to the movement of the pendulum support, communicated to it by the swinging *pendulum*. See *flexure (pendulum support)*.

flexure (pendulum support).—The forced movement of a pendulum support caused by the motion of the swinging *pendulum*.

The horizontal component of the force acting on the *knife edge* of a swinging *pendulum* causes the support to move in unison with the *pendulum*, thereby affecting the period of its *vibration*. Though very small, this *flexure* of the *pendulum* support necessitates the application of a *correction* to the *pendulum* period. There are several methods of ascertaining the amount of the *flexure*, of which two have been used in the work of the U. S. Coast and Geodetic Survey: the static method, by which the displacement caused by a known force is measured in linear units; and the optical method, using an *interferometer* to measure the actual displacement in terms of wave lengths of light. The term *flexure* is also applied to the bending of a swinging *pendulum*, account of which is taken in absolute determinations of the value of *gravity*. See *flexure (pendulum)*.

focal length.—See under *focus (lens)*.

focus (lens).—The point to which rays of light converge after passing through a lens system.

If the incident rays are parallel they come to a focus in the (primary) focal plane, and it is the distance along the axis of the lens system from the *second nodal point* of the lens to this plane which is called the focal length of the lens.

focus: sidereal.—The position of the principal focal plane of a lens system.

A camera or *telescope* is said to be in sidereal focus when incident rays from a great distance come to a *focus* in the plane of the photographic plate or of the *reticle*. Sometimes called the solar focus.

foot.—A *unit of length* equal to 12 *inches* exactly or to one-third of a *yard*.

foot plate (leveling).—A disk of metal used as a rod support at a *turning point* in *leveling operations*.

One type of foot plate had a rod point, such as a knob, attached to its upper side, while the lower side had small projections to prevent lateral motion of the foot plate when it was pressed against the ground. In another type, the upper surface of the foot plate was dish-shaped (concave). The use of foot plates as rod supports has been superseded by metal pins driven firmly into the ground.

foresight (general).—A sight on a new survey point, made in connection with its determination; or a sight on a previously established point, to close a circuit.

foresight (leveling).—A reading on a rod held on a point whose *elevation* it is intended to determine.

The foresight may be on a point of unknown *elevation*, or on a previously established *bench mark* to close a circuit. Foresights are sometimes called minus sights, as they are usually subtracted from the *elevation* of the instrument (H. I.) to obtain the *elevation* of the rod point. This is not always the case, as the new point may be at a greater *elevation* than the instrument, as a mark on a wall, or a point on the roof of a tunnel. The term foresight is preferred over minus sight.

foresight: extra (leveling).—The rod reading made at an *instrument station* in a *line of levels* and on a *leveling rod* standing on a *bench mark* or other point NOT in the continuous *line of levels*.

In spirit leveling there may be one or more extra foresights from a single *instrument station* or *set-up*, but there can be only one *backsight* and one *foresight* from any one *instrument station*.

forward azimuth.—See under *azimuth: geodetic*.

fourth-order traverse.—See under *traverse*.

fractional section (United States public-land surveys).—See under *section*.

fractional township (United States public-land surveys).—See under *township*.

free-air anomaly.—See under *anomaly*.

free-swinging pendulum.—See under *pendulum*.

French legal meter.—See under *meter*.

fundamental tables: deformation of the geoid and its effect on gravity.—Tables giving the deformation of the *geoid* and its effect on *gravity*, computed for masses of unit density extending to various distances above and below the surface of the *geoid*.

Fundamental tables serve as the basis for the preparation of special tables corresponding to particular assumptions respecting density, *isostasy*, etc. Several such fundamental tables have been prepared, each designed for a particular effect:

a). Fundamental Tables for Reducing Observed Gravity Values, by G. Cassinis and P. Dore (1937) determine the direct effect on *gravity* of masses of unit density extending to various distances above and below *sea level*. This direct effect is known as the Hayford effect; it neglects the differences of *elevation* between the *spheroid* and the *geoid*.

b). Fundamental Tables: The Deformation of the Geoid and its Effect on Gravity (U. S. Coast and Geodetic Survey Special Publication No. 199) by Walter D. Lambert and Frederic W. Darling (1936) determine the indirect effect of masses of unit density extending to various distances above and below *sea level;* this indirect effect is known as the *Bowie effect;* it takes into account the differences of *elevation* between the *spheroid* and the *geoid*.

c). Fundamental Tables for the Deflection of the Vertical (a U. S. Coast and Geodetic Survey publication now in press) by Frederic W. Darling give the horizontal effect (*deflection of the vertical*) of masses of unit density extending to various distances above and below *sea level*. For mathematical development and formulas, see Bulletin Geodesique: No. 57, January-February-March 1938 and New Series No. 9, July 1, 1948.

G

gal.—An *acceleration* of one centimeter per second per second.

The gal is the unit of *acceleration* of the c. g. s. system of units and, since about 1930, has been used by the U. S. Coast and Geodetic Survey in stating values of *gravity*. Before that date, the *dyne*, a unit of force, was used for the purpose. (The real unit was dyne/gram.) While the term gal has not been formally adopted by the International Association of Geodesy, it is now in general use in those countries where *gravity* observations are being made. It is expressed symbolically by $cm/sec.^2$ A milligal is 0.001 gal. The term gal is not an abbreviation; it was invented to honor the memory of Galileo.

geländereduktion.—See *terrain correction.*

general base map.—See under *map: Topographic Map of the United States.*

general highway and transportation map.—See under *map: Transportation Map of the United States.*

general topographic map.—See under *map: Topographic Map of the United States.*

general utility map.—See under *map: Topographic map of the United States.*

general utility map of the United States.—See under *map: Topographic Map of the United States.*

general utility topographic map of the United States.—See under *map*: *Topographic Map of the United States.*

geocentric coordinates.—See under *coordinates.*

geocentric latitude.—See under *latitude.*

geocentric parallax.—See under *parallax: diurnal parallax.*

geodesic.—A *geodesic line.*

geodesic line.—A line of shortest distance between any two points on any mathematically defined surface. Also termed a *geodesic.*

While, in *geodetic* work, a geodesic line on a *spheroid* of reference is sometimes called a *geodetic line, geodetic* as applied to lines is going out of use, and *geodesic* is preferred.

geodesy.—The science which treats mathematically of the figure and size of the earth.

The term geodesy is often used to include both the science which must depend upon determinations of the figure and size of the earth from direct measurements made on its surface (*triangulation, leveling,* astronomic and *gravity* determinations), and the art which utilizes the scientific determinations in a practical way and is usually termed *geodetic surveying* or geodetic engineering.

geodetic.—Signifying basic relationship to the earth in which the curvature of its *sea-level* surface is taken into account.

In horizontal *control surveys,* the term geodetic is applied to operations and results based on the *ellipsoid of revolution* (*spheroid*). In *spirit leveling, elevations* are referred—or intended to be referred—to the *geoid*. In determining *elevations* by *vertical angles, elevations* are referred (in the ideal case where *deflections of the vertical* are available) to the *ellipsoid of revolution*. In ordinary practice, since *deflections of the vertical* are not usually available, the results are a mixture, and are referred to neither surface exactly.

geodetic azimuth.—See under *azimuth.*

geodetic azimuth mark.—See under *azimuth mark.*

geodetic control.—See under *control.*

geodetic coordinates.—See under *coordinates.*

geodetic datum.—See under *datum.*

geodetic equator.—See under *equator.*

geodetic latitude.—See under *latitude.*

geodetic leveling.—See under *leveling.*

geodetic line.—The shortest-distance line between any two given points on the surface of the *spheroid.*

Sometimes called a *geodesic line,* a geodetic line is a line of double curvature, and usually lies between the two *normal section lines* which the two points determine. If the two terminal points are in nearly the same latitude, the geodetic line may cross one of the normal section lines. It should be noted that, except along the equator and along the meridians, the geodetic line is not a plane curve and cannot be sighted over directly. However, for conventional triangulation the lengths and directions of geodetic lines differ inappreciably from corresponding pairs of normal section lines.

geodetic longitude.—See under *longitude.*

geodetic meridian.—See under *meridian.*

geodetic parallel.—See under *parallel.*

geodetic position.—See under *position.*

geodetic survey.—See under *survey.*

geodetic surveying.—See under *surveying.*

geographic; geographical.—Signifying basic relationship to the earth considered as a globe-shaped body.

The term geographic is applied alike to data based on the *geoid* and on a *spheroid*. In *geodetic surveys* in this country, coordinated data consisting of *latitudes, longitudes, azimuths,* and lengths of lines, are recorded and published under the general title of *geographic positions*. For particular usage of the two forms, geographic, geographical, see *-ic; -ical.*

geographic center.—The geographic center of an area on the earth has been defined as that point on which the area would balance if it were a plate of uniform thickness. In other words, it is the center of gravity of that plate.

The geographic center of continental United States (exclusive of Alaska) is in the eastern part of Smith County, Kansas, latitude 39°50′, longitude 98°35′. The geographic centers of the various States are given in the U. S. Geological Survey Bulletin 817, "Boundaries, Areas, Geographic Centers, and Altitudes of the United States and the Several States."

geographic coordinates.—See under *coordinates.*

geographic exploration survey.—See under *survey.*

geographic latitude.—See under *latitude.*

geographic longitude.—See under *longitude.*

geographic meridian.—See under *meridian.*

geographic parallel.—See under *parallel.*

geographic position.—See under *position.*

geographic survey.—See under *survey.*

geographical mile.—See under *mile: nautical.*

geoid.—The figure of the earth considered as a *mean sea-level* surface extended continuously through the continents.

The actual geoid is an *equipotential surface* to which, at every point, the plumb line (direction in which *gravity* acts) is perpendicular. It is the geoid which is obtained from observed *deflections of the vertical,* and is the surface of reference for astronomical observations and for geodetic leveling. Theoretical geoids obtained with computed values of *deflections of the vertical* include the *compensated geoid* and the *isostatic geoid.*

geoid: compensated.—A theoretical *geoid* derived from the actual *geoid* by the application of computed values of the *deflection of the vertical* which depend upon the *topography* and *isostatic compensation.*

The data upon which to base the effect of *topography* and *isostatic compensation* are obtained from readings of *topographic maps;* the effect is then computed in accordance with the assumptions made with respect to *isostasy,* that is, the depth and distribution of *isostatic compensation.* A method for accomplishing this was developed by Hayford, who accepted the *Pratt theory of isostasy.* If the theory and assumptions with respect to *isostasy* were exact and there were no *anomalies,* the compensated geoid would agree with the *spheroid* of reference.

geoid: isostatic.—An ideal *geoid* derived from the *spheroid* of reference by the application of computed values of the *deflection of the vertical* which depend upon the *topography* and *isostatic compensation.*

The computed values of the *deflection of the vertical* used in obtaining the isostatic geoid are similar to those for the *compensated geoid,* but of opposite signs. If the theory and assumptions with regard to *isostasy* were exact and there were no *anomalies,* the isostatic geoid would agree with the actual *geoid.*

geoid contour.—A line on the surface of the *geoid* of constant *elevation* with reference to the surface of the *spheroid* of reference.

Geoid contours represent differences in *elevation* between the *geoid* and the *spheroid.* Geoid contours depend on the surface of reference. The same *geoid* referred to different surfaces of reference will give different sets of geoid contours.

geologic survey.—See under *survey.*

geological survey.—See under *survey.*

geometric latitude.—See under *latitude: parametric (geometric or reduced) latitude.*

geometric map projection.—See under *map projection: perspective map projection.*

geophysics.—The science of the earth with respect to its structure, composition, and development.

Geophysics is a branch of experimental physics dealing with the earth, including its atmosphere and hydrosphere. It includes the sciences of dynamical geology and physical geography, and makes use of *geodesy,* geology, seismology, meteorology, oceanography, magnetism, and other earth sciences in collecting and interpreting earth data. Geophysical methods have been applied successfully to the identification of underground structures in the earth and to the search for structures of a particular type, as for example, those associated with oil-bearing sands.

gisement.—The *angle* between the *grid meridian* and the *geographic meridian.*

The term "gisement" is used in connection with the *military grid,* sometimes being called the "declination of grid north," and reckoned east and west from geographic north. Gisement is not used with the *State coordinate systems,* where the corresponding *angle* on the *transverse Mercator grid* is the convergence of the local with the central geographic meridian, and is designated by $\Delta\alpha$. In the *Lambert grid,* the angle is known as the "mapping angle," designated by θ, and called the "theta angle."

globe.—A spherical body. See under *globe: celestial globe; terrestrial globe.*

globe: celestial.—A sphere, on the outer surface of which, by means of symbols and reference lines, stars are shown in positions and magnitudes determined from the earth.

Usually shown also are the outlines of the constellations or star groups. Essentially, a celestial globe is a sphere to the outside of which star maps have been fitted.

globe: terrestrial.—A sphere, on the outer surface of which, by means of symbols and reference lines, the features of the surface of the earth are shown in relative positions.

Essentially, a terrestrial globe is a sphere to the outside of which *maps* of the surface of the earth have been fitted. See *globe, gore.*

globe, gore.—A lune-shaped *map* which may be fitted to the surface of a *globe* with a negligible amount of distortion.

A *terrestrial* or *celestial globe* may be constructed by covering a sphere with a complete set of *maps,* each having the form of a lune of such narrow width that it may be mounted on the sphere without appreciable stretching or shrinking.

globe, horizon ring.—A graduated ring fitted to a *globe* in such manner that its plane contains the center of the *globe,* and it can be adjusted into the plane of the *horizon* for any point on the *globe.*

The horizon ring is used in scaling *angles* around the *horizon* for a given point.

globe, meridian ring.—A graduated ring fitted to a *globe* in such manner that its plane contains the poles of the *globe,* and it can be adjusted into the plane of any given *meridian* on the globe.

A meridian ring is used for scaling *angles* along a *meridian.*

globe, time dial.—An adjustable circular disk, graduated in time units (0 hours to 24 hours), attached to a *globe* with its center coincident with a pole of the *globe.*

A time dial can be adjusted to show the relation between local *time* and the *time* of any other *meridian.*

globular map projection.—See under *map projection.*

gnomonic map projection.—See under *map projection.*

Golofnin Bay datum.—See under *datum.*

goniasmometre.—A compact surveying instrument for observing *horizontal angles* and *bearings,* and consisting of a vertical cylinder divided horizontally into two parts: the lower edge of the upper part is graduated in circular measure and revolves on the lower part, which carries a *vernier* on its upper edge. A magnetic needle is centered in the upper part, which is also provided with slits or a *telescope* for sighting purposes.

An instrument used in France, and serving the same purposes as a *surveyor's compass* or *transit.*

goniometer.—In *surveying,* an instrument for measuring *horizontal angles* or *directions,* such as a *theodolite.*

In general, goniometer is a term applied to various instruments for measuring *angles,* as in crystallography, anthropology, etc.

grad (grade).—An *angle* at the center of a circle, subtended by one four-hundredth part of its circumference. See *angle (general).*

grade.—Rate of slope or degree of inclination. See *gradient.* Example: a 1 to 100 grade; a 1-percent grade.

grade correction, tape.—See under *tape.*

gradient (topography).—A *grade* expressed as a tangent of the *angle of inclination.*

Example: a 1 to 100 *grade* is a gradient of .01.

gradienter.—An attachment to an engineer's *transit* with which an *angle of inclination* is measured in terms of the tangent of the *angle* instead of in degrees and minutes.

A gradienter may be used as a telemeter in observing horizontal distances.

graduation.—See under *division.*

graticule.—A network of lines representing geographic parallels and meridians forming a *map projection.*

Gravatt level.—See under *leveling instrument.*

Gravatt leveling rod.—See under *leveling rod.*

gravimeter (geodesy).—A weighing device or instrument of sufficient sensitivity to register variations in the weight of a constant mass when the mass is moved from place to place on the earth and thereby subjected to the influence of *gravity* at those places.

A typical gravimeter consists of a spring which changes in length under the load of a constant mass as the instrument is moved from place to place and thereby affected by changes in *gravity.* Gravimeters are employed in determining differences in the intensity of *gravity* between an initial or base station at which the value of gravity is known or assumed and at nearby points for which values of *gravity* are desired. Gravimeters are also termed gravity meters.

gravitation.—In general, the mutual attraction between masses of matter (bodies). In *geodesy,* the mutual attraction between the earth and bodies on or near its surface.

Gravitation is the component of *gravity* which acts towards the earth.

gravitation: constant of.—The Newtonian constant of gravitation, being the constant G in the formula $F=G\frac{m_1m_2}{r^2}$, where F is the attractive force between two bodies of masses m_1 and m_2 expressed in grams, r is the distance in centimeters between the two bodies, and the time unit is the *mean solar second.*

Various values of the constant of gravitation which have become available in recent years are as follows:

(a) $(6.670\pm0.005)\times10^{-8}$ c. g. s. units

This is by Paul R. Heyl, reported in the Bureau of Standards Journal of Research, December 1930. It is the value used in U. S. Coast and Geodetic Survey Special Publication No. 199, Tables for Determining the Form of the Geoid and its Indirect Effect on Gravity, 1936.

(b) $(6.664\pm0.002)\times10^{-8}$ dyne. $cm^2.g^{-2}$

This is the value adopted in the Smithsonian Physical Tables, edition of 1934.

(c) $(6.673\pm0.003)\times10^{-8}$ $cm.^3.g^{-1}.sec^{-2}$

This is the most recent determination by Heyl, reported in the Journal of Research of the National Bureau of Standards, July 1942. It agrees so well with the 1930 result that the conclusion is reached that, for the method used (the *torsion balance*), the limit of possibilities for increasing the *precision* has been reached.

gravity.—That force which tends to pull bodies towards the earth: that is, to give bodies weight.

Gravity is the resultant of two opposing forces: *gravitation* and the *centrifugal force* due to the *rotation* of the earth. See *gravity: intensity of gravity.*

gravity: Clairaut's Theorem.—A theorem connecting the *ellipticity* of the earth with the coefficient of $\sin^2\phi$ of the *formula for theoretical gravity* or with the difference between *gravity* at the poles and *gravity* at the equator.

This means that every *gravity* formula implies a particular value for the *ellipticity* of the *spheroid* of reference. Let g_p and g_e represent *gravity* at the poles and at the *equator,* respectively, and let the *formula for theoretical gravity* be written $g=g_e\,(1+\beta\sin^2\phi+\text{smaller terms})$. Also, assume values for ϕ of 90° and 0°, and neglect the smaller terms.

Then $\beta=\frac{g_p-g_e}{g_e}$ and Clairaut's Theorem is written as follows: $\beta=\frac{g_p-g_e}{g_e}=\frac{5m}{2}-f+$smaller terms, f being the *ellipticity* and m the ratio of *centrifugal force* at the *equator* to *gravity* at the equator, or $\frac{\omega^2a,}{g_e}$, where ω is the angular velocity of *rotation* of the earth in *radians* per second and a is the semi-major axis (equatorial radius) of the *spheroid.*

As originally stated by Clairaut, the smaller terms were neglected. For an exact *ellipsoid* we have, to a high degree of *accuracy,* the formula

$$\beta=\frac{5m}{2}-f+\frac{17}{14}mf.$$

Upon first consideration, Clairaut's Theorem may seem paradoxical: an increase in the *flattening of the earth, f,* apparently diminishing the increase in *gravity* from *equator* to pole. This is explained by the fact that the theorem applies, not to values on the physical surface of the *ellipsoid,* but to values on a *level surface*—any *level surface* lying outside all attracting matter. In the case of the *geoid,* or *sea-level surface,* which has a comparatively small amount of matter outside it, Clairaut's Theorem is applied by means of certain conventions in the reduction to that surface of values of *gravity* observed outside the physical surface of the earth. If the *ellipticity* of the physical surface of the earth is conceived to change but that surface still remain a *level surface,* the distribution of density within the *level surface* must change accordingly, and Clairaut's Theorem will still hold.

The increase in *gravity* from *equator* to poles according to the *International Gravity Formula* has been analyzed by Hammer as follows:

Centrifugal acceleration	+3.39 *gals*	
Free-air effect	+6.63	net
Mass-shape effect	−4.85	+1.78 *gals*
Total change, *equator* to poles	+5.17 *gals*	

The free-air effect is due to the difference of the distances from the center of the earth of the attracted particle when at a pole and when at the *equator*, the attractions being in the inverse ratio of the squares of the respective distances. But the inverse-square law is correct only when the dimensions of the attracting body are negligible in comparison with the distances involved, a condition that does not hold in the present instance. Near its surface, the terrestrial *ellipsoid* does not attract in exact accordance with the inverse-square law. The *correction* which is applied to the free-air effect to care for this condition is the mass-shape effect given in this and the next paragraph.

If the terrestrial *ellipsoid* were homogeneous, the free-air effect and the mass-shape effect would be more nearly equal, and the increase in *gravity* from *equator* to poles would be composed as follows:

Centrifugal acceleration $= mg =$	+3.39 *gals*	
Free-air effect $= 2fg = 5mg/2 =$	+8.48	net +0.85
Mass-shape effect $= 9mg/4 =$	−7.63	*gal*
Total change, *equator* to poles $= 5mg/4 =$	+4.24 *gals*	

gravity: direction of; direction of the force of gravity.—The direction indicated by a plumb line.

It is perpendicular to the surface of the *geoid*. See *nadir, zenith*.

gravity: formula for theoretical.—A formula expressing *gravity* on the *spheroid* of reference in terms of *geographic position*, it being assumed that the *spheroid* of reference is a *level surface*.

If the *spheroid* of reference is one of *revolution*, all *meridians* are alike and the *longitude* can not appear in the formula (see *gravity formula, longitude term*); furthermore, since the *spheroid* is symmetrical with respect to the *equator*, only even functions of the *latitude* can appear in the formula. *Gravity* increases toward the poles, both because the centrifugal *acceleration* due to the earth's *rotation* decreases as a pole is approached and because the mass-attraction of the *spheroid* is greater at the poles than at the equator.

Gravity on the surface of a *spheroid of revolution* is expressed by either of the following commonly used formulas:

$$g = g_e\ (1 + \beta \sin^2 \phi + \text{smaller terms})$$

$$g = g_{45}\ (1 - \gamma \cos 2\phi + \text{smaller terms})$$

where g is *gravity* on the surface of the *spheroid* in *geographic latitude* ϕ, g_e is *gravity* at the *equator*, g_{45} is gravity at *latitude* 45°, and β and γ are constants. For numerical values of g_e and constants appearing in the first formula above, see *gravity: Clairaut's Theorem; Helmert's gravity formula of 1901; International Gravity Formula;* and *gravity formula, longitude term*.

In the approximate formulas, the smaller terms are often omitted. If this is done, our surface of reference is a *spheroid of revolution* lying, at latitude 45°, 19 *meters* above an exact *ellipsoid* of *revolution* having the same axes as the spheroid.

gravity: Helmert's gravity formula of 1901.—A development of the *formula* for *theoretical gravity* utilizing the *gravity* observations available at the time (1901), but not fitted to any preassigned value of the earth's *ellipticity*.

Referred to the Potsdam value of absolute *gravity*, Helmert's gravity formula of 1901 is as follows:

$$g = 978.030\ (1 + 0.005302 \sin^2 \phi - 0.000007 \sin^2 2\phi).$$

While the *International Gravity Formula* was based on a preassigned value of the earth's *ellipticity*, the above formula was not, but it was used in determining a value for that *ellipticity*, namely 1/298.2. The coefficients $g_e = 978.030$ and $\beta = 0.005302$ were determined from the observations.

Attempts made to determine the coefficient of $\sin^2 2\phi$ in the same way were abandoned because of the large *probable errors* obtained, and the value 0.000007 was assumed from theoretical considerations based on the work of Darwin and Wiechert on a self-attracting rotating mass of the size of the earth. Such a mass, unless homogeneous, will not take on the form of an exact *ellipsoid*, but will be depressed in middle *latitude* below an exact *ellipsoid* having the same major and minor axes. The amount of this depression will depend upon the law used for the variation of density with respect to distance from the center of the earth. Darwin and Wiechert assumed different laws, but both found a depression of 3 meters in *latitude* 45°. This depression corresponds to the difference between 0.0000059 and 0.000007, the corresponding coefficients in the International and Helmert formulas.

gravity: Helmert's gravity formula of 1915.—A development of the *formula for theoretical gravity*, based on a *triaxial ellipsoid*, and including a *longitude term*. See *gravity formula, longitude term*.

gravity: intensity of.—The force with which *gravity* acts, expressed in suitable units.

Intensity of gravity may be expressed either as a force (*force of gravity*) expressed in *dynes*; or as an *acceleration* expressed as centimeters per second per second. In the geodetic work of the U. S. Coast and Geodetic Survey, before 1930, intensity of gravity was stated as a force, in *dynes*; since then, it has been stated as an *acceleration*, in *gals*.

gravity: International Gravity Formula.—A development of the *formula for theoretical gravity*, based on the assumptions that the *spheroid* of reference is an exact *ellipsoid* of *revolution* having the dimensions of the International Ellipsoid of Reference (Madrid, 1924), rotating about its minor axis once in a *sidereal day*; that the surface of the *ellipsoid* is a *level surface*; and that *gravity* at the *equator* equals 978.049 *gals*.

Omitting terms which are so small as to be negligible for practical purposes, the International Gravity Formula is as follows:

$$g = 978.049\ (1 + 0.0052884 \sin^2 \phi - 0.0000059 \sin^2 2\phi).$$

The International Gravity Formula was adopted by the International Association of Geodesy at the Stockholm meeting, 1930. The purpose was not primarily to represent the *gravity* observations then available, although the $g_e = 978.049$ *gals* was based on those observations, but rather it was intended to put the determination of the *figure of the earth* from *gravity* data on the same basis as the determination of its figure from *deflections of the vertical*. This formula is based on the Potsdam value for absolute *gravity*.

gravity anomaly.—See under *anomaly: free-air anomaly*.

gravity apparatus: Brown gravity apparatus.—See under *Brown gravity apparatus.*

gravity formula.—See under *gravity: formula for theoretical gravity.*

gravity formula, longitude term.—A suggested additional term for the *formula for theoretical gravity,* derived from the *longitude* on a *spheroid* of reference having three unequal axes.

With this additional term, the *formula for theoretical gravity* would be as follows:

$g = g_e\ [1+\beta \sin^2 \phi - \beta_1 \sin^2 2\phi + c \cos^2 \phi \cos 2\ (\lambda-\lambda_0)]$
where g_e is the mean value of *gravity* at the *equator,* and c, like β and β_1 is a dimensionless number.

As always, the *formula for theoretical gravity* implies a *spheroid* of definite shape. When a longitude term of the type indicated above is included, the *spheroid* is no longer an *ellipsoid* of *revolution,* but an *ellipsoid* having three unequal axes (*triaxial ellipsoid*), the shortest of which is its polar axis (corresponding to the axis of *rotation* of the earth), while the two longer ones lie in the plane of the *equator.* The longer equatorial axis lies in the *meridian* plane λ_0 and $\lambda_0 \pm 180°$; the shorter in the *meridian* plane $\lambda_0 \pm 90°$. These two equatorial axes or diameters differ by $\pm 4\ ca$; the difference of each semiaxis from a mean is $\pm ca$, and from each other $\pm 2\ ca$.

The form of the longitude term is not arbitrary. In theoretical investigations on the attraction of nearly spherical bodies, it is convenient to work with spherical harmonics. These are mathematical expressions involving *latitude* and *longitude.* They are of different degrees, the harmonics increasing in complexity as their degree increases.

The additional term involving *longitude* in the *gravity formula* is the spherical harmonic term of lowest degree not already present, though in partly disguised form, in the ordinary *gravity formula* and not excluded from it for sufficient theoretical reasons. (The excluded terms are proportional to $\cos \phi \cos \lambda$, $\cos \phi \sin \lambda$, $\sin \phi$, $\sin 2\phi \cos \lambda$, and $\sin 2\phi \sin \lambda$.) The idea of an *ellipsoid* of three unequal axes as a possible surface of reference is by no means new. There was, however, no continuing interest in the idea until Helmert and his assistant, Berroth, each published in 1915 his calculations on which were based *gravity formulas* containing a longitude term of the type given above. *Helmert's gravity formula of 1915* is as follows:

$g = 978.052\ [1+0.005285 \sin^2\phi - 0.000007 \sin^2 2\phi + 0.000018 \cos^2 \phi \cos 2\ (\lambda+17°)]$.

In the formula, east *longitude,* λ, is positive. The maximum equatorial semiaxis (radius) is 115 *meters* longer than the mean equatorial semiaxis (radius) and 230 *meters* longer than the minimum. The maximum axis lies in the *meridian* plane of $\lambda = 17°$ west and 163° east of Greenwich. The minimum axis lies in the meridian plane $\lambda = 73°$ east and 107° west of Greenwich. The mean *ellipticity* of a *meridian* is 1/296.7.

Since 1915, various discussions of the accumulating mass of *gravity* data have tended to confirm the reality of a longitude term of the same general size and character as that proposed by Helmert. Studies of the *deflections of the vertical* have likewise tended to confirm that general result. This does not mean, however, that a *triaxial ellipsoid* is likely to find favor as a surface of reference for *triangulation* and *deflections of the vertical.* The mathematical complications of such a surface are too great. And since one of the purposes of studying *gravity* observations is to determine the *figure of the earth* and to compare the results with those obtained from *deflections of the vertical,* it is convenient to use the same surface of reference for both and therefore omit the longitude term from the *formula for theoretical gravity.*

It would appear from the most recent study of the longitude term (Jeffreys, 1942–3), that a longitude term of the type derived by Helmert and others is not the only spherical harmonic term needed to represent existing widespread variations of *gravity.* Jeffreys confirmed the existence of a longitude term of the general character and magnitude just discussed, and tentatively determined a few other spherical harmonic terms of low degree; he found, however, that the number and distribution of existing *gravity* observations were inadequate for a satisfactory determination of those terms.

The argument against including a longitude term in the *formula for theoretical gravity* applies with even greater force to the additional terms found by Jeffreys. The mathematical complexities attending the use of a figure of reference which these additional terms would imply are too great for practical problems. The significance of the longitude term and of the other terms proposed by Jeffreys, which are also longitude terms of a sort, is mainly geophysical. These terms represent widespread systematic variations in *gravity* and in *deflections of the vertical.* They represent also general widespread departures from isostatic equilibrium and therefore imply the existence of long-continuing stresses in the earth's crust. The problems they represent are geological and geophysical: problems of how the configuration of the continents and oceans on the known geological structures are related to the departures from equilibrium which are implied by the additional terms.

While it is of great geological and geophysical interest to improve the *formula for theoretical gravity* by the addition of spherical harmonic terms of low degree, the question of how far to continue the addition of such terms must be left to the future. It seems probable, however, that consideration of the usefulness of this procedure will limit such additions to spherical harmonic terms of rather moderate degree.

gravity meter.—See under *gravimeter.*

gravity station.—A *station* at which observations are made to determine the value of *gravity.*

great circle.—The line of intersection of the surface of a sphere and any plane which passes through the center of the sphere.

The shortest distance between any two points on a sphere is along the *arc* of a great circle connecting the two points. Great circles on the *celestial sphere* which are given particular designations are the *equator,* the *ecliptic, meridians, hour circles, prime verticals, colures,* and *horizons.* The shortest distance on an *ellipsoid* of *revolution* is a *geodetic line* (a *geodesic*), which is not a plane curve except for the *equator* (a circle) and the *meridians* (ellipses). In *cartography,* the *gnomonic* is the only *map projection* on which a great circle is represented, in all instances, as a straight line. The *gnomonic projection* for a *map* of the United States computed by the U. S. Coast and Geodetic Survey is based on a sphere having the same volume as the *ellipsoid of reference* (*Clarke spheroid of 1866*).

great circle line.—In *land surveying,* the line of intersection of the surface of the earth and the plane of a *great circle* of the *celestial sphere.*

The term great circle line is proposed for use in descriptions of methods for establishing *parallels* of *latitude* (*standard parallels* and correction lines) in *surveys* of the public lands of the United States. Since the earth is not a sphere, a great circle line is but an approximation to a *great circle* and, due to the *deflection of the vertical,* will not, as surveyed, lie in a single plane.

Greenwich Civil Time.—See under *time.*

Greenwich Meridian.—See under *meridian.*

Greenwich Sidereal Time.—See under *time.*

Gregorian Calendar.—See under *calendar.*

grid.—A network composed of two sets of uniformly-spaced straight lines intersecting in right angles.

In surveying and mapping, the term grid is applied to a *plane-rectangular coordinate system* imposed upon a *geographic coordinate* system. See *State coordinate systems.*

grid: military.—See under *military grid.*

grid azimuth.—See under *azimuth.*

grid bearing.—See under *bearing.*

grid coordinates.—See under *coordinates.*

grid distance.—See under *grid length.*

grid inverse.—The computation of *grid length* and *grid azimuths* from *grid coordinates.*

grid length.—The distance between two points as obtained by computation from the *plane rectangular coordinates* of the points.

In the *State coordinate systems,* a grid length differs from a *geodetic length* by the amount of a correction based on the *scale factor* for the given line.

grid meridian.—See under *meridian.*

guide meridian (United States public-land surveys).—See under *meridian.*

Gunter's chain.—See under *chain.*

H

hack (United States public-land surveys).*—A horizontal V-shaped notch, cut into the trunk of a tree at about breast height.

hack chronometer.—See under *chronometer.*

half section (United States public-land surveys).—See under *section.*

hand level.—See under *leveling instrument.*

hanging level.—See under *level.*

Harrebow-Talcott method, latitude determination.—See under *zenith-telescope method, latitude determination.*

Hassler base-line measuring apparatus.—See under *base apparatus.*

Hayford-Bowie method of isostatic reduction.—A method of computing the effect of *topography* and *isostatic compensation* on *gravity* by which the effect of *topography* is computed directly and then corrected for the effect of *isostatic compensation.*

The mechanics of this method involve the use of the *Hayford gravity templates.*

Hayford-Bullard (or Bullard) method of isostatic reduction.—A method by which the topographic effect of an infinite slab of density 2.67 and a thickness equal to the *elevation* of the *gravity station* is first computed, and then corrected for curvature of the *sea-level* surface and for difference of *elevation* between the station and the *topography.*

The first step in the computation gives the ordinary Bouguer correction for *topography:* the second step takes account of the departure of the actual *topography* from a smooth cap or plate of thickness equal to the *elevation* of the station.

The application of the *curvature correction* for the lettered zones reduces the effect of the plane slab to that of a plateau or cap extending to the outer limits of those zones and curved to the mathematical surface of the earth. Account is taken of the *topography* by applying a *correction* for the deviations of the *topography* from the surface of the plateau or cap.

This method was devised by E. C. Bullard as a substitute for the *Hayford-Bowie method of isostatic reduction* for the lettered zones of the *Hayford gravity templates;* it is described in U. S. Coast and Geodetic Survey Special Publication No. 232, Pendulum Gravity Measurements and Isostatic Reductions, by Clarence H. Swick, 1942.

Hayford deflection templates.—See under *template (templet).*

Hayford effect (gravity).—See under *fundamental tables: deformation of the geoid and its effect on gravity (a).*

Hayford gravity anomalies; Hayford anomalies.—See under *anomaly: isostatic anomaly.*

Hayford gravity templates.—See under *template (templet).*

height of instrument.—1. In *spirit leveling:* the height of the *line of sight* of a *leveling instrument* above the adopted *datum.* 2. *Stadia surveying:* the height of the center of the *telescope* (*horizontal axis*) of *transit* or *telescopic alidade* above the ground or station mark. 3. *Trigonometrical leveling:* the height of the center of the *theodolite* (*horizontal axis*) above the ground or station mark.

heliocentric parallax.—See under *parallax: annual.*

heliotrope.—An instrument composed of one or more plane mirrors, so mounted and arranged that a beam of sunlight may be reflected by it in any desired direction.

Placed over a survey station, a heliotrope is used to direct a beam of sunlight toward a distant survey station, where it can be observed with a *theodolite.* It provides an excellent target in observing *horizontal directions,* such targets having been observed on at distances of over 150 miles and approaching 200 miles. There are several types of heliotropes, carrying various names, but differing only in details of mechanical arrangement and construction. Heliotropes are sometimes used for sending messages, using the Morse code conveyed by short and long flashes of light; when especially equipped for the purpose, such instruments are termed heliographs.

hemispherical map.—See under *map.*

high-water line.—The place on the bank or shore up to which the presence and action of water is so usual and long continued as to impress on the *bed of the stream* a character distinct from that of the *banks* with respect to vegetation and the nature of the soil.

The high-water line is the *boundary line* between the *bed* and the *bank of a stream*. The mean high-water line usually determines the boundary of the land of the riparian proprietor.

highway map.—See under *map.*

homalographic map projection.—See under *map projection.*

horizon.—A *great circle* on the *celestial sphere* whose plane is perpendicular to the direction of the plumb line.

The direction of the plumb line is sometimes referred to as the *direction of gravity*, and *direction of the force of gravity*. In *surveying*, the plane of the horizon is determined by means of a *spirit level.* See *horizon: apparent (visible) horizon.*

horizon: apparent (visible).—The irregular line along which rays from the point of observation are tangent to the surface of the earth.

The apparent horizon is the line where the visible surface of the earth appears to meet the sky. When the apparent horizon is formed by the surface of a body of water, it is sometimes used as a reference in observing *vertical angles.* See *horizon: dip of.*

horizon: artificial.—A device consisting of a plane reflecting surface which can be adjusted to coincide with the plane of the *horizon.*

One form of artificial horizon consists of a dish or trough filled with mercury, or an amalgam of mercury and tin, the upper surface of which is free, and assumes a horizontal position. Another form is a plane mirror of glass or other material, equipped with *spirit levels* and leveling screws so that it can be adjusted into the plane of the *horizon.*

In observing a celestial body such as a star or the sun, the *angle* is measured between the body as seen direct (with *transit* or *theodolite*) or reflected (in the horizon glass of a *sextant*) and its image as seen reflected in the artificial horizon: this is a *vertical angle,* and is double the *altitude* of the body.

horizon: closing the.—Measuring the last of a series of *horizontal angles* at a station required to make the series complete around the *horizon.*

At any station, the sum of all *horizontal angles* between adjacent lines should equal 360°. The amount by which the sum of the *observed angles* fails to equal 360° is the *error of closure.* This is distributed as a *correction* for closure among the *observed angles* to bring their sum to exactly 360°. The *error* and the *correction* are of opposite signs.

horizon: dip of.—The *vertical angle* between the plane of the *horizon* and a line tangent to the *apparent (visible) horizon.*

horizontal angle.—See under *angle.*

horizontal axis (theodolite or transit).—The axis about which the *telescope* of a *theodolite* or *transit* rotates when moved vertically.

It is the axis of *rotation* which is perpendicular to the *vertical axis* of the instrument and to the *axis of collimation* of the *telescope.* It should coincide with the line through the centers of the pivots which support the *telescope.* For an instrument in complete adjustment, it occupies a horizontal position, and when the *telescope* is rotated around it, the *axis of collimation* will define a *vertical plane:* deviations from this condition are measured with a *striding level* or with a *hanging level.*

horizontal direction.—A *direction* in a horizontal plane.

horizontal parallax.—See under *parallax: diurnal parallax.*

Horrebow-Talcott method, latitude determination.—See under *zenith-telescope method, latitude determination.*

hour angle.—The angle between the plane of the *hour circle* passing through a celestial body and the plane of the *celestial meridian.*

The hour angle is reckoned from the *meridian* (0 hours or 0°) westward through 24 hours (360°). It may be measured by the *angle* at the pole between an *hour circle* and the *meridian,* or by the *arc* of the *equator* which is intercepted by those circles.

hour circle.—Any *great circle* on the *celestial sphere* whose plane is perpendicular to the plane of the *celestial equator.*

Hour circles are also called circles of *declination.* The hour circle which contains the *zenith* is identical with the *celestial meridian.*

hygrometric.—Relating to the relative humidity or comparative amount of moisture in the atmosphere.

Since the atmosphere penetrates the pores or cells of material bodies in varying degrees depending upon the substances of which they are composed, the amount of moisture which it contains will affect the shapes and dimensions of certain instruments and equipment used in *surveying* and mapping. For this reason it is necessary to select materials which are not sensitive to hygrometric conditions for the construction of *leveling rods, plane-table* sheets, etc., and for the construction and printing of maps.

hypsographic feature.*—A *topographic feature* with *elevations* portrayed with reference to *sea level.*

hypsographic map.—See under *map.*

hypsography.*—*Topography* (*relief*), referred to a *sea-level datum.* The science or art of describing *elevations* (heights) of land surfaces with reference to *sea level.*

hypsometer.*—An instrument used in determining *elevations* of points on the earth's surface in relation to *sea level* by determining atmospheric pressure through observation of the boiling point (temperature) of water at each point. Also an instrument used in forestry for determining heights of trees.

Determination of heights of mountain summits by observing the boiling point of water on the summits has been much used by explorers.

The term hypsometer is also used to designate one who measures *elevations* of the land, or who constructs *maps* or models to show land *elevations.* This is a rare use.

hypsometric.—Relating to *elevation* above a *datum,* usually *sea level.*

In a limited sense, hypsometric relates to *elevations* above *sea level* determined with a *hypsometer.*

hypsometric feature.*—Disapproved. See under *hypsographic feature.*

hypsometric map.—See under *map: hypsographic.*

hypsometry.*—The art of determining, by any method, surface *elevations* on the earth with reference to *sea level.*

The determination of *elevations* by means of either *mercurial* or *aneroid barometers* is sometimes called barometric hypsometry.

hypsometry: barometric.—See under *hypsometry.*

I

-ic; -ical.—Suffixes employed to convert certain terms into adjective form, the two adjectives derived from the same root word sometimes having slightly different meanings, but often employed according to custom or personal preference, without differentiation.

While it seems desirable to employ the shorter suffix, -ic, for adjectives having a direct and intimate relationship to the root word, and the longer form, -ical, to form adjectives of more general and broader applicability, this cannot be adopted as an exact procedure, and it is proposed that custom be considered, and in the work of this Bureau, the forms be used as recommended below.

1. geodetic, geodetical; geodesic, geodesical.—Each of these terms has appeared in technical literature. The longer forms, geodetical, and geodesical, are now practically obsolete. Geodesic was at one time employed to designate a class of *spirit leveling,* but at present is largely limited to use in a mathematical sense. The following forms, defined elsewhere, are proposed for use in this Bureau: *geodetic azimuth; geodetic equator; geodetic latitude; geodetic longitude; geodetic meridian; geodetic parallel; geodetic position; geodetic survey;* and *geodesic line.*

2. astronomic; astronomical.—Astronomers have preferred and used the longer form, *astronomical.* Surveyors have employed both forms, often without apparent differentiation in meaning, though they have accepted the astronomers' use of *astronomical* for terms of general applicability. In the publications of this Bureau, with some exceptions, the shorter form, *astronomic,* has been employed in recent years where there is an intended contrast with the term *geodetic,* and it is believed that this practice should be adopted insofar as is compatible with established practice. The following terms, defined elsewhere, are accordingly proposed for use in this Bureau: *astronomic azimuth; astronomic coordinates; astronomic equator; astronomic latitude; astronomic longitude; astronomic meridian; astronomic parallel;* astronomic station; and *astronomical day; astronomical leveling;* astronomical methods; *astronomical refraction; astronomical theodolite; astronomical time; astronomical transit; astronomical traverse; astronomical triangle; astronomical unit.*

3. geographic; geographical.—The following forms are proposed for use in this Bureau: *geographic center; geographic equator; geographic latitude; geographic longitude; geographic meridian; geographic parallel; geographic position; geographic survey;* geographical boundary; *geographical mile;* geographical organization, survey, or society.

4. geologic; geological.—The following forms are proposed for use in this Bureau: geologic data; geologic investigation or survey; geological organization, survey, or society; geological era; geological time.

5. geophysical.—The form geophysical is used to the exclusion of any other that might be derived from the term *geophysics.*

iced-bar apparatus.—See under *base apparatus.*

identification posts.—Posts of wood or other suitable material, appropriately marked and inscribed, and placed near *survey stations* to aid in their recovery and identification.

Identification posts also serve as guard posts, calling attention to the stations which they serve, thus giving protection against their accidental destruction. Designated as supplemental posts for survey monuments, identification posts were recommended for use in a report of the Committee on Control adopted by the Federal Board of Surveys and Maps, March 14, 1939.

idle pendulum.—See under *pendulum.*

impersonal micrometer.—See under *micrometer: transit micrometer.*

inch.—A *unit of length* defined by the equivalence: 1 *meter* equals 39.37 inches exactly.

The relationship, 1 meter equals 39.37 inches, was established by Act of Congress, July 28, 1866, but was put into practical effect only after the United States had received copies of the *International Prototype Meter.* In 1893, the Superintendent of Standard Weights and Measures, with the approval of the Secretary of the Treasury, declared the *International Prototype Meter* to be the *standard* of length, with the customary unit, the *yard,* to be derived therefrom in accordance with the Act of July 28, 1866. The *yard* is accepted as equal to 36 inches exactly. See under *meter: National Prototype Meter.*

inclination of the horizontal axis.—The *vertical angle* between the *horizontal axis* of a surveying or astronomical instrument and the plane of the *horizon.*

Inclination of the horizontal axis is measured with a *striding level* or a *hanging level.* It causes the *axis of collimation* of a *theodolite* or *transit* to describe an inclined plane instead of a *vertical plane* when the *telescope* is rotated about the *horizontal axis* of the instrument. This produces an *error* in an observed *horizontal direction* of an object not situated in the plane of the *horizon,* and requires the application of a *correction for inclination of the horizontal axis.*

inclination of the horizontal axis: correction for.—A *correction* applied to an observed *horizontal direction* to eliminate any *error* that may have been caused by the *horizontal axis* of the instrument not being exactly horizontal.

If the *horizontal axis* of the instrument is not exactly horizontal, the *axis of collimation* will not cut the *horizon* at a point directly underneath (or above) an observed point: that is, a plane described by the *axis of collimation* when the *telescope* is rotated about its *horizontal axis* will not be a *vertical plane.* As the *inclination of the horizontal axis* may involve two conditions: the failure of the *horizontal* and *vertical axes* of the instrument to meet exactly at a right angle, and a possible deviation of the *vertical axis* from the direction defined by the plumb line, a determination of this *correction* requires that both the inclination of the axis and the *altitude* of the observed object be known.

index correction (leveling).—See under *correction.*

index map.—See under *map.*

index of refraction.—See under *refraction.*

indirect leveling.—See under *leveling.*

indirect observations.—See under *observation.*

initial point (United States public-land surveys).*—The point from which is initiated the survey of the *principal meridian* and *base line* controlling the survey of the public lands within a given area.

For list of initial points, *principal meridians,* and *base lines,* and the areas governed thereby, see page 138, section 141, General Land Office Manual of Instructions for the Survey of the Public Lands, edition 1930.

instrument station (leveling).—See under *station.*

instrumental error.—See under *error.*

instrumental parallax.—See under *parallax.*

intensity of gravity.—See under *gravity.*

interferometer.—An optical instrument which employs the principle of the interference of light waves to determine the amount of displacement. It is used in length standardizations, in comparing end standards, etc.

The interferometer employed in observations with the *pendulum* is a slightly modified form of the instrument used by Michelson, its inventor. With this instrument the slight movement (*flexure*) of the *receiver* which is caused by the swinging *pendulum* is measured.

interior angle.—See under *angle.*

International Map of the World map projection.—See under *map projection: International Map of the World.*

international meter.—See under *meter.*

International Prototype Meter.—See under *meter.*

intersection: point of.—See under *curve.*

intersection station.—See under *station*.

interval: stadia (leveling).—The length of rod subtended between the top and bottom cross wires in the *leveling instrument* as seen projected against the face of the *leveling rod.*

invar.—An alloy of nickel and steel having a very low *coefficient of thermal expansion.*

Invar was discovered by C. E. Guillaume of the International Bureau of Weights and Measures, Paris. Having a *coefficient of thermal expansion* of about one-twenty-fifth that of steel, it has replaced steel in the construction of tapes for measuring geodetic *base lines,* and is used in other places where a metal of that characteristic is desired. Invar is used in the construction of some *leveling rods* and *first-order leveling instruments.* Invar is also used in the construction of *pendulums.*

invar pendulum.—See under *pendulum.*

invar rod.—See under *leveling rod.*

invar tape.—See under *base tape.*

invariable pendulum.—See under *pendulum.*

inverse: geographic.—See under *inverse position computation.*

inverse position computation.—The derivation of the length, and the *forward* and *back azimuths* of a *geodetic line* by computation based on the known *geodetic positions* of the ends of the line.

This is called an inverse position computation (or an inverse) because it reverses the usual order of computation, where a new *geodetic position* is derived by computation, using its *azimuth* and distance from a known *geodetic position.*

island.*—A body of land extending above and completely surrounded by water at *mean high water.*

The above definition is of universal application in *surveying* and mapping operations in the United States, and is fully supported by federal court decisions relating to the ownership of land. In foreign affairs, however, international negotiations are affected by various and different conceptions of what constitutes the boundary line between the land and the water.

isometric (conformal) latitude.—See under *latitude.*

isoperimetric curve.—A line on a *map projection* along which there is no variation from exact *scale.*

There are two isoperimetric curves passing through every point on an *equal-area map projection.* This characteristic gives that class of projections some preference for *engineering maps.*

isostasy.—A condition of approximate equilibrium in the outer part of the earth, such that the gravitational effect of masses extending above the surface of the *geoid* in continental areas is approximately counterbalanced by a deficiency of density in the material beneath those masses, while the effect of deficiency of density in ocean waters is counterbalanced by an excess of density in the material under the oceans.

The basic principle of isostasy is that the masses of prismatic columns of the outer part of the earth extending to some constant depth below the surface of the *geoid* are proportional to the areas of their *sea-level* sections, regardless of their surface *elevations.* The depth below *sea level* to which these hypothetical columns extend is known as the *depth of isostatic compensation,* and is somewhere between 60 and 70 *statute miles.* The area of the *sea-level* section of a unit hypothetical column for which *isostatic compensation* is ordinarily complete has not been determined; it may be uniform for all parts of the earth, or may vary with the character of the *relief* in the same continental regions.

While isostasy is generally accepted as a proven principle, there are several theories as to the relative distribution of the matter producing this condition of equilibrium, the two principal ones being those of Airy and of Pratt.

The Pratt theory, announced by J. H. Pratt in 1855, assumed that the continents and islands project above the average *elevation* of the solid surface of the earth because of material of less density beneath them: the higher the surface, the lesser the density below. Under the Pratt theory, complete equilibrium exists at some uniform depth below sea level: the same depth for ocean areas as for land masses. It is the theory accepted by geodesists and by many geologists, and used in the investigations of isostasy by Hayford and Bowie of the U. S. Coast and Geodetic Survey.

The Airy theory, announced by G. B. Airy in 1855, postulated the continents and islands as resting hydrostatically on highly plastic or liquid material, with roots or projections penetrating the inner material of the earth, just as icebergs extend downward into the water. The greater the *elevation,* the deeper the penetration. It has been called the "Roots of Mountain Theory," and has the support of some geologists. The fundamental difference between the two theories is that Pratt postulated uniform depth with varying density, while Airy postulated uniform density with varying depth. The term "isostasy," meaning equal pressure, was first proposed by C. E. Dutton in a paper entitled "On Some of the Greater Problems of Physical Geology," delivered before the Philosophical Society of Washington on April 27, 1889, and printed in Bulletin No. II of that Society.

isostatic adjustment.—The process of restoring and maintaining that condition of equilibrium in the so-called crust of the earth which is known as *isostasy.*

The distribution of material in the outer part of the earth is undergoing continual change by the operation of erosion, sedimentation, and other natural forces. The unbalanced condition which would naturally result from such disturbing processes is offset by the movement of material at considerable depths below the surface of the earth. See *isostatic compensation: depth of isostatic compensation.*

isostatic anomaly.—See under *anomaly.*

isostatic compensation.—The departure from normal density of material in the lower part of a column of the earth's crust which balances (compensates) land masses (*topography*) above *sea level* and deficiency of mass in ocean waters, and produces the condition of approximate equilibrium of the earth's crust known as *isostasy*.

isostatic compensation: depth of.—The depth below *sea level* at which the condition of equilibrium known as *isostasy* is complete.

Investigations of geodetic and gravimetric data in the United States determine a depth of isostatic compensation of between 60 and 70 *statute miles*.

isostatic geoid.—See under *geoid*.

isostatic reduction: Bullard method of.—See under *Hayford-Bullard (or Bullard) method of isostatic reduction.*

isostatic reduction: Hayford-Bowie method of.—See under *Hayford-Bowie method of isostatic reduction.*

isostatic reduction: Hayford-Bullard (or Bullard) method of.—See under *Hayford-Bullard* (or *Bullard*) *method of isostatic reduction.*

J

Jacob's staff.—A single staff or pole used for mounting a *surveyor's compass* or other instrument.

Used in place of a tripod, a Jacob's staff was fitted with a ball-and-socket joint at its upper end, by means of which the instrument was adjusted to a level position; the foot was fitted with a metal shoe which facilitated pressing the staff firmly into the ground. Many of the early *land surveys* in this country were made with *surveyor's compasses* mounted on Jacob's staffs.

Julian calendar.—See under *calendar*.

junction (leveling).—The place where two or more lines of levels are connected together.

junction bench mark.—See under *bench mark*.

junction detail.—See *detail: junction*.

junction figure.—A triangulation figure in which three or more *triangulation arcs* meet, or two or more *arcs* intersect.

K

knife edge (pendulum).—A suspension bearing used in the support of a *pendulum*.

The knife edge bears on a plane. The *Mendenhall pendulum* used in the work of the U. S. Coast and Geodetic Survey originally had an agate knife edge mounted in its head, which was stirrup-shaped; this agate knife edge rested on an agate *plane* which was rigidly mounted in the *receiver*. In apparatus made since 1898, the positions of knife edge and *plane* are reversed, the plane being attached to the *pendulum*, and the knife edge mounted in the *receiver*.

Kripniyuk-Kwiklokchun datum.—See under *datum*.

L

Lambert azimuthal polar map projection.—See under *map projection*.

Lambert central equivalent map projection upon the plane of the meridian.—See under *map projection: Lambert zenithal (azimuthal) equal-area*.

Lambert conformal map projection.—See under *map projection*.

Lambert equal-area meridional map projection.—See under *map projection*.

Lambert grid.—An informal designation for a *State coordinate system* based on a *Lambert conformal map projection* with two *standard parallels*.

Lambert zenithal (azimuthal) equal-area map projection.—See under *map projection*.

land boundary.—See under *boundary*.

land court.—A tribunal established for the purpose of administering legislative statutes relating to *land boundaries* and titles.

There are land courts in Massachusetts and in Hawaii.

land forms.*—The shapes into which the earth's surface is sculptured by natural forces.

A land form is subject to portrayal by various means or to the interpretation of its probable origin, cause, or history. The form in all cases is the same. Whether it is a *topographic form* or a *physiographic form* depends upon the use for which it is considered. The term land form is used extensively in place of and with the meaning of the more restricted term, *physiographic form*. It is sometimes written as one word, landform, but the two-word spelling, land form, is preferred.

land survey.—See under *surveying: land surveying*.

land surveying.—See under *surveying*.

landmark.—Any *monument* or material mark or fixed object used to designate the location of a *land boundary* on the ground. Any prominent object on land which may be used in determining a location or a *direction*.

Laplace azimuth.—See under *azimuth*.

Laplace azimuth mark.—See under *azimuth mark*.

Laplace condition.—See under *Laplace equation*.

Laplace equation.—The equation which expresses the relationship between *astronomic* and *geodetic azimuths* in terms of *astronomic* and *geodetic longitudes and geodetic latitude*. A usual form is

$$\alpha_A - \alpha_G = -(\lambda_A - \lambda_G)\sin\phi_G$$

in which α_A and λ_A are *astronomic azimuth* and *longitude*, α_G, λ_G, and ϕ_G are *geodetic azimuth, longitude,* and *latitude* respectively. The signs depend upon convention. As written above, north *latitudes* and west *longitudes* are considered positive.

The Laplace condition (expressed by the Laplace equation) arises from the fact that a *deflection of the vertical* in the plane of the *prime vertical* will give a difference between *astronomic* and *geodetic* *longitude* and between *astronomic* and *geodetic azimuth;* or, conversely, that the observed differences between *astronomic* and *geodetic* values of the *longitude* and of the *azimuth* may both be used to determine the *deflection* in the plane of the *prime vertical.* This *deflection* cannot have two values at the same place, and the imposition of the Laplace condition forces a consistency between them. Since *longitudes* can be carried through *triangulation* with very good *accuracy* and *azimuths* cannot, the practice is to compute the value of the *deflection* for *azimuth* from the *deflection* in the *prime vertical* obtained from the *longitude.* The value of the *azimuth* thus obtained is known as a *Laplace azimuth.*

The symbol α_L is proposed for *Laplace azimuths,* for use in formulas and wherever a special symbol is desirable. In computing a *control survey,* the *deflection of the vertical* at the initial station will affect any Laplace equations in the net. In the readjustment of the horizontal *control survey net* of the United States which introduced the *North American datum of 1927, azimuth control* was furnished by *Laplace azimuths* distributed throughout the net. In the investigation of the *figure of the earth* and *isostasy* which produced the International Ellipsoid of Reference, the Laplace condition was expressed as follows:

$$\cos \phi' (\lambda_A - \lambda') = -\cot \phi' (\alpha_A - \alpha')$$

The symbols marked with a prime (′) represent geodetic values, those with a subscript letter $(_A)$ represent astronomic values. The use of a subscript letter $(_G)$ for geodetic values is preferred.

The Laplace equation is so-called after Pierre Simon Laplace (1749–1827), who derived a general form for it when comparing the shape of the earth with a mathematical figure. (Mécanique Céleste, 1799, by Marquis de Laplace. English translation by Nathaniel Bowditch, published in 1832, vol. 2, p. 385.)

Laplace station.—A *triangulation* or *traverse station* at which a *Laplace azimuth* is determined.

At a Laplace station both *astronomic longitude* and *astronomic azimuth* are determined.

large scale.—See under *map scale: fractional.*

lat.—See under *latitude: difference of latitude (plane surveying).*

latitude (general).—A coordinate distance, linear or angular, from an east-west reference line.

latitude (on a sphere).—The *angle* at the center of a sphere between the plane of the *equator* and the line to the point on the surface of the sphere.

Some problems of *geodesy* and *cartography* are greatly simplified by the use of latitudes on a sphere which has some definite relationship (as equal area or equal volume) to the *spheroid.*

latitude (plane surveying).—The perpendicular distance in a horizontal plane of a point from an east-west axis of reference.

The *difference of latitude* of the two ends of a line is frequently called the latitude of the line, and defined as the *orthographic projection* of the line on a reference *meridian.* The latitude (as above defined) of the middle of a line is also referred to as the latitude of the line.

latitude: astronomic.—The *angle* between the plumb line and the plane of the *celestial equator.* Also defined as the *angle* between the plane of the *horizon* and the axis of *rotation* of the earth.

Astronomic latitude is the *latitude* which results directly from observations on celestial bodies, uncorrected for *deflection of the vertical (station error)* which, in the United States, may amount to as much as 25″. Astronomic latitude applies only to positions on the earth, and is reckoned from the *astronomic equator* (0°), north and south through 90°.

latitude: authalic (equal-area).—A *latitude* based on a sphere having the same area as the *spheroid,* and such that areas between successive *parallels of latitude* are exactly equal to the corresponding areas on the *spheroid.*

Authalic latitudes are used in the computation of *equal-area map projections.* For mathematical definition and discussion consult U. S. Coast and Geodetic Survey Special Publication No. 67, Latitude Developments Connected with Geodesy and Cartography, by O. S. Adams, 1921.

latitude: celestial.—The *arc* of a *great circle* perpendicular to the *ecliptic,* intercepted between the *ecliptic* and the object whose *latitude* is to be defined.

Celestial latitude is not the same as *astronomic latitude,* and does not enter into usual problems of *surveying.*

latitude: difference of latitude (plane surveying).—The *orthographic projection* of a line on a *meridian* of reference.

By custom, this term has been shortened to *latitude* or *lat.,* which is frequently used where difference of latitude is intended. It is north or positive, and sometimes termed the northing, for a line whose *azimuth* or *bearing* is in the northwest or northeast quadrant; it is south or negative, and sometimes termed the southing, for a line whose *azimuth* or *bearing* is in the southeast or southwest quadrant.

latitude: geocentric.—The *angle* at the center of the earth between the plane of the *celestial equator* and a line to a point on the surface of the earth.

Geocentric latitude is used as an auxiliary *latitude* in some computations in astronomy, geodesy, and cartography, in which connection it is defined as the *angle* formed with the major axis of the ellipse (meridional section of the *spheroid*) by the radius vector from the center of the ellipse to the given point. In astronomic work, geocentric latitude is also called *reduced latitude,* a term that is sometimes applied to *parametric latitude* in *geodesy* and cartography. The geocentric and *isometric latitudes* are approximately equal.

latitude: geodetic.—The *angle* which the *normal* to the *spheroid* at a point makes with the plane of the *geodetic equator.*

Geodetic latitudes are reckoned from the *equator,* but in the horizontal *control survey* of the United States they are computed from the latitude of station Meades Ranch as prescribed in the *North American datum of 1927.* In recording a *geodetic position,* it is essential that the *geodetic datum* on which it is based be also stated. A geodetic latitude differs from the corresponding *astronomic latitude* by the amount of the meridional component of the local *deflection of the vertical (station error)* which, in this country, may amount to more than 25″.

latitude: geographic.—A general term, applying alike to *astronomic latitudes* and *geodetic latitudes.*

latitude: isometric (conformal).—An auxiliary *latitude* used in the conformal mapping of the *spheroid* on a sphere.

By transforming *geographic latitudes* on the *spheroid* into isometric latitudes on a sphere, a *conformal map projection* (the Mercator) may be calculated, using spherical formulas, for the plotting of *geographic* data. For a mathematical definition of isometric latitude see U. S. Coast and Geodetic Survey Special Publication No. 67, Latitude Developments Connected with Geodesy and Cartography, by O. S. Adams, 1921. The *isometric* and *geocentric latitudes* are approximately equal.

latitude: parametric (geometric or reduced).—The *angle* at the center of a sphere which is tangent to the *spheroid* along the *geodetic equator,* between the plane of the *equator* and the radius to the point intersected on the sphere by a straight line perpendicular to the plane of the *equator* and passing through the point on the *spheroid* whose parametric latitude is defined.

Parametric latitude is an auxiliary *latitude* used in problems of *geodesy* and *cartography.* For mathematical definition see U. S. Coast and Geodetic Survey Special Publication No. 67, Latitude Developments Connected with Geodesy and Cartography, by O. S. Adams, 1921. In astronomical work, when the term reduced latitude is used, *geocentric latitude* is meant.

latitude: rectifying.—The *latitude* on a sphere such that a *great circle* on it has the same length as a *meridian* on the *spheroid,* and such that all lengths along a *meridian* from the *equator* are exactly equal to the corresponding lengths on the *spheroid.*

Rectifying latitude is an auxiliary *latitude* used in problems of *geodesy* and *cartography.* For mathematical definition see U. S. Coast and Geodetic Survey Special Publication No. 67, Latitude Developments Connected with Geodesy and Cartography, by O. S. Adams, 1921.

latitude: variation of.—A small periodic change in the *astronomic latitude* of points on the earth, due to *variation of the pole.*

latitude equation.—See under *equation.*

latitude level.—See under *level.*

least squares.—A mathematical method of determining the most probable values of a series of quantities from a set of observations greater in number than are necessary to determine those quantities.

Credit for the discovery in 1770 of the method of least squares is sometimes given to Lagrange, although his method was lost or forgotten for some time. Credit for the discovery is more often given to Gauss, who used it in 1795 but did not publish his results until 1809, while it had been demonstrated by Adrain in 1808. Laplace demonstrated it in 1810 and in 1812, and its theory was compared with practice by Bessel in 1818. It rests upon the mathematical demonstration that where each of a very large number of observations of any quantity is of the same quality as the others, the most probable value of the quantity is the one for which the sum of the squares of the *residual errors* (or *corrections*) is a minimum. If the observations are of unequal *weight,* then the most probable value is the one for which the sum of the squares of the weighted residuals is a minimum. In survey work, the method of least squares provides a means of obtaining the most probable values of position and associated data, and at the same time fully coordinating and correlating those data. The adjusted survey data distributed by the U. S. Coast and Geodetic Survey are obtained by the method of least squares. Least squares have also been designated as "minimum squares."

left bank.—See under *bank of stream.*

Legendre's theorem.—The *angles A, B,* and *C* of a spherical triangle whose sides are *a, b,* and *c,* supposed very small with respect to the radius of the sphere, are equal to the corresponding *angles* of a plane triangle whose sides are *a, b,* and *c,* increased each by one-third the *spherical excess* of the triangle.

(Alternate definition.)

In two triangles, one a spherical triangle whose sides a, b, and c are very small in comparison with the radius of the sphere and the other a plane triangle having sides of the same length as the spherical triangle, the *angles* A, B, and C of the spherical triangle are greater than the corresponding *angles* of the plane triangle, each by one-third of the *spherical excess* of the spherical triangle.

The use of Legendre's theorem greatly simplifies the treatment of spherical triangles in *geodetic* work, by permitting their solution as plane triangles. This theorem is named after the French mathematician, Adrien Marie Legendre (1752–1833), who demonstrated it.

length correction: tape.—See under *tape.*

length equation.—See under *equation.*

lens: achromatic.—See under *achromatic lens.*

lens: aplanatic.—See under *aplanatic lens.*

lens axis.—See under *principal axis.*

level: bull's-eye.—See under *level: circular.*

level: chambered spirit.—A level tube with a partition near one end which cuts off a small air reservoir, so arranged that the length of the bubble can be regulated.

level: circular.—A *spirit level* having the inside surface of its upper part ground to spherical shape, the outline of the bubble formed being circular, and the *graduations* being concentric circles.

This form of *spirit level* is used where a high degree of precision is not required, as in plumbing a *level rod* or setting an instrument in approximate position. Also termed universal level; bulls-eye level.

level: first-order.—See under *leveling instrument.*

level: hand.—See under *leveling instrument.*

level: hanging.—A *spirit level* so mounted that, when in use, its level tube is lower in elevation than its points of support.

A hanging level literally hangs from the member of the surveying or astronomical instrument whose position with reference to a horizontal line it measures. It is used in place of a *striding level* to measure the inclination of the *horizontal axis* of the *broken-telescope transit.*

level: latitude.—A sensitive *spirit level* attached to the *telescope* of an instrument employed for observing *astronomic latitude,* in such manner that when the *telescope* is clamped in position, the level measures, in a *vertical plane,* variations in the direction of the *line of collimation.*

A latitude level is of greater sensitivity than the level which is attached to the *finder circle* of an astronomical instrument to aid in placing its *telescope* at the proper inclination for bringing a selected celestial object into the field of view at the expected time.

level: precise.—See under *leveling instrument.*

level: spirit (general).—A small closed vessel of transparent material (glass), having the inside surface of its upper part curved (circular) in form; the vessel is nearly filled with a fluid of low viscosity (alcohol or ether), enough free space being left for the formation of a bubble (blister) of air and gas, which will always assume a position at the top of the vessel.

Many *surveying* operations depend upon the instrumental establishment of the plane of the *horizon,* which is accomplished with the aid of a spirit level. For work of high *precision,* where exact establishment of the plane of the *horizon* is desired, a spirit level of great sensitivity is employed to determine deviations from that plane, and corresponding *corrections* are then applied to the observations.

There are two types of spirit levels used in surveying: one having the curved surface spherical in form, producing a bubble of circular outline, and defined under the term *circular level.* The other, and much more generally used type, has a vessel in the form of a circular tube, the longitudinal axis of which is also circular in form. It is defined under the term spirit level, and is the type usually referred to when that term is used.

level: spirit.—A closed glass tube (vial) of circular cross section, its center line also forming a circular *arc*, its interior surface being ground to precise form; it is nearly filled with ether or other liquid of low viscosity, enough free space being left for the formation of a bubble of air and gas.

This is the type of spirit level used on those surveying and astronomical instruments which make use of the *horizon* (or *zenith*) as a reference of observations, and which require more than an *approximate* adjustment to such reference. When in adjustment, a tangent to the center of the level bubble defines a horizontal line in the plane of the longitudinal axis of the level tube, with an *accuracy* and *precision* which depend upon the quality of the workmanship and the sensitivity of the level. The sensitivity, sometimes termed sensibility, of a *spirit level* depends upon the radius of curvature of its longitudinal section: the longer the radius, the more sensitive the level. The sensitivity is rated by equating the linear length of a division between graduation marks on the level tube and its angular value at the center of curvature of the tube. Example: stride level of *meridian telescope* No. 9 (U. S. Coast and Geodetic Survey), 1 division = 2 mm. = 1.884″ at 12° C. A usual value for the sensitivity of the long level on a surveyor's *transit* is: 1 division = 3/20 inch = 30″.

level: striding.—A *spirit level* so mounted that it may be placed above and parallel with the *horizontal axis* of a surveying or astronomical instrument, and so supported in use that it may be used to measure the inclination of the *horizontal axis* to the plane of the *horizon.*

Generally, the *spirit level* of a striding level is of greater than average sensitivity, and its mounting has supports in the form of inverted wyes which rest directly upon the pivots on which the *telescope* of the instrument rotates. It is used to make the inclination of the *horizontal axis* quite small and then to measure the magnitude of any remaining inclination.

level: universal.—See under *level: circular level.*

level: wind, spirit level.—Lack of parallelism between the axis of a *spirit level* vial and the line joining the centers of its supports.

When wind (pronounced to rhyme with find) is present, if the *spirit level* is rocked on its supports, the bubble will respond with a longitudinal movement.

level axis: spirit.—The line tangent to the surface of a spirit-level tube (vial) against which the bubble forms, at the center of the graduated scale of the level, and in the plane of the tube (vial) and its center of curvature. Also called axis of the level, axis of the level bubble.

When the level bubble is in the center of the *graduations*, and the plane through the center line of the level tube and its center of curvature is vertical, the spirit level axis will be horizontal.

level constant.—See under *constant.*

level correction (leveling).—See under *correction.*

level line: duplicate.—A line of *spirit leveling* composed of two single lines run over the same route, but in opposite directions, and using different *turning points.*

level line: multiple.—Two or more single lines of *spirit leveling* run between the same terminal points, but along different routes.

level line: simultaneous.—A line of *spirit leveling* composed of two single lines run over the same route, both in the same direction, but using different *turning points.* Also called a simultaneous double line.

level net.—See under *survey net.*

level surface.—A surface which at every point is perpendicular to the plumb line or the direction in which *gravity* acts.

A level surface is an *equipotential surface.* The surface of a body of still water is a level surface (see *water leveling*). The surface of the ocean, if changes caused by tides, currents, winds, atmospheric pressure, etc., are not considered, is a level surface. The surface of the *geoid* is a level surface. Any line lying in a level surface is a *level line.* In a *survey* of a limited area, a level surface is sometimes treated as a plane surface. Level surfaces are approximately spheroidal in shape, the distance between any two level surfaces decreasing with increase of *latitude.* For example: a level surface which is 1,000 *meters* above the mean surface of the sea at the *equator* is 995 *meters* above that surface at the poles.

level trier.—An apparatus for use in measuring the angular value of the *divisions* of a *spirit level.*

A level trier may consist of a beam mounted on a stable base: one end of the beam is hinged to the base, the other end can be moved vertically by means of a micrometer screw, the angular amount of the movement being measured with the *micrometer.* The *spirit level* is mounted on the beam, and the angle through which the beam moves while the bubble of the *spirit level* travels the length of a *division* is measured with the *micrometer.*

leveling: astronomical.—The determination of the figure of the *geoid* from *deflections of the vertical.*

leveling: barometric.—A method of determining differences of *elevation* from differences of atmospheric pressure observed with a *barometer.*

By the application of certain *corrections* and the use of what is sometimes called the "barometric formula," a difference of atmospheric pressure at two places is transformed into a difference of *elevations* of those places. If the *elevation* of one station above a *datum* (as *sea level*) is known, the approximate *elevations* of other stations connected with it by barometric leveling can be known. By using *barometers* of special design, and including several stations of known *elevation* in a series of occupied stations, the *accuracy* of the *elevations* determined for the new stations is increased. *Corrections* are applied for temperature, *latitude*, index of barometer, closure of circuit, *diurnal variation* in atmospheric pressure, etc.

leveling: direct.—The determination of differences of *elevation* by means of a continuous series of short horizontal lines, the vertical distances from which to adjacent ground marks are determined by direct observations on graduated rods with a *leveling instrument* equipped with a *spirit level.*

leveling: first order.—*Spirit leveling* conforming to the following criteria: all first-order leveling to be divided into sections of 1 to 2 kilometers in length; each section to be leveled over in both forward and backward directions; the results of the two runnings over a section not to differ by more than 4.0 millimeters times the square root of the length of the section in kilometers (4.0 *mm.*$\sqrt{K}$), the equivalent of which is 0.017 foot times the square root of the length of the section in miles (0.017 *ft.*$\sqrt{M}$).

The above designation and criteria were recommended by the Federal Board of Surveys and Maps in May 1925. First-order leveling was formerly called precise leveling and leveling of high precision.

leveling: geodetic.—*Spirit leveling* of a high order of *accuracy*, usually extended over large areas, to furnish accurate vertical *control* as a basis for the control in the vertical dimension for all surveying and mapping operations.

Spirit leveling follows the *geoid* and its associated *level surfaces* which are irregular, rather than any mathematically determined *spheroid* or *ellipsoid* and associated regular level surfaces.

leveling: indirect.—The determination of differences of *elevation* from (1) *vertical angles* and horizontal distances, as in *trigonometric leveling;* (2) comparative *elevations* derived from values of atmospheric pressure determined with a *barometer*, as in *barometric leveling;* and (3) *elevations* derived from values of the boiling point of water determined with a *hypsometer*, as in *thermometric leveling*.

leveling: precise.—See under *leveling: first-order leveling*.

leveling: second-order.—*Spirit leveling* which does not attain the quality of *first-order leveling*, but does conform to the following criteria: lines between *bench marks* established by *first-order leveling* to be run in only one direction, using first-order instruments and methods; or other lines to be divided into sections, over which forward and backward runnings are to be made; the closure in either case not to exceed 8.4 millimeters times the square root of the length of the line (or section) in kilometers (8.4 *mm.*$\sqrt{K}$), the equivalent of which is 0.035 foot times the square root of the length of the line (or section) in miles (0.035 *ft.*$\sqrt{M}$).

The above designation and criteria were recommended by the Federal Board of Surveys and Maps in May 1925.

leveling: spirit.—The determination of *elevations* of points with respect to each other, or with respect to a common *datum*, by means of an instrument using a *spirit level* to establish a horizontal *line of sight*.

A *spirit level* is attached to a *telescope* in such a way that the *axis of the level* and the *line of collimation* may be made parallel, and the level adjusted so that its axis is horizontal. The difference of readings on vertical rods held on two different points is the difference in *elevation* of the points. If the *elevation* of one point is known, the other also becomes known. By a series of progressive *level lines*, each comprising the observed values at a single station, the *elevations* of a series of points (*bench marks*) are determined. Instruments used in spirit leveling are of various designs, to satisfy needs based on speed, cost, *accuracy*, and *precision*. Among such types are the *hand level*, the *wye level*, the *dumpy level*, the *Fischer level*, etc. Spirit leveling has been classified by the Federal Board of Surveys and Maps according to the *accuracy* of the results obtained as follows: *first-order leveling, second-order leveling*, and *third-order leveling*.

leveling: thermometric.—The determination of *elevations* above *sea level* from observed values of the boiling point of water.

The temperature at which water boils at any point on the earth depends upon the weight of the incumbent atmosphere at that point. See *hypsometer*.

leveling: third-order.—*Leveling* which does not attain the quality of *second-order leveling*, but does conform to the following criteria: lines of third-order leveling shall not be extended more than 30 miles from lines of *first-* or *second-order leveling*, and must close upon lines of equal or a higher order of *accuracy;* closing errors must not exceed 12 millimeters times the square root of the length of the line in kilometers (12 *mm.* $\sqrt{K}$), the equivalent of which is 0.05 foot times the square root of the length of the line in miles (0.05 *ft.* $\sqrt{M}$).

The above designation and criteria were recommended by the Federal Board of Surveys and Maps in May 1925. Third-order leveling is used for subdividing loops of *first-* and *second-order leveling*, and to provide local vertical control for detailed surveys.

leveling: trigonometric.—The determination of differences of *elevations* by means of observed *vertical angles*, combined with lengths of lines. See *vertical angulation*.

leveling: water.—A method of obtaining relative *elevations* by observing heights with respect to the surface of a body of still water.

The surface of a body of still water, as of a lake, is a *level surface* (*equipotential surface*), and the relative *elevations* of objects along its shores may be obtained by taking the differences of their heights with respect to the surface of the water. It is with this meaning that the term *"water levels"* is generally used.

leveling instrument: dumpy level.—A leveling instrument in which the *telescope* is permanently attached to the leveling base, either rigidly or by a hinge that can be manipulated by means of a micrometer screw.

The dumpy level takes its name from the dumpy appearance of the early type of this instrument, the *telescope* of which was short and had a large object glass. Dumpy levels constitute one of two principal classes of leveling instruments in which most leveling instruments used in surveying belong. The other class is represented by the *wye* (Y–) *level*. The *Fischer level* used by the U. S. Coast and Geodetic Survey on *first-* and *second-order work* is a dumpy level. Method of mounting the *telescope* and not its shape is the identifying characteristic of a dumpy level.

leveling instrument: Egault level.—A French instrument having the *spirit level* attached to a level bar which also carries wyes in which the *telescope* rests.

In the so-called *wye level*, the *spirit level* is attached to the *telescope*, and is reversed with it. In Egault's level, the *telescope* is reversed in the wyes without disturbing the *spirit level*.

leveling instrument: first-order level.—A leveling instrument designed for the attainment of first-order results. See under *leveling: first-order*.

A first-order instrument is generally characterized by special features of design, and by superior workmanship in construction. A general, but not always exact, distinction between instruments used in *first-order* and *second-order leveling* and other leveling instruments is the following: a first-order level is carefully adjusted, and any *instrumental errors* remaining are determined by observation and applied as *corrections* to the observed differences of *eleva-*

tion; in using other leveling instruments, a careful adjustment of the instrument is made, and thereafter no account is taken of *errors* remaining in the instrument. An important characteristic of leveling instruments used in *first-order work* at the present time is a mirror and prism arrangement by means of which the level bubble and the level rod can be viewed at the same time, while a micrometer-screw control of the *telescope* makes it possible to bring the level bubble to the center of its tube at the instant of reading the rod. There have been a number of different designs of leveling instruments used in this country on *first-order leveling* (formerly called *precise leveling*), but all such work by the U. S. Coast and Geodetic Survey is now done with a *Fischer level.*

leveling instrument: Fischer level.—The official designation of the instrument used by the U. S. Coast and Geodetic Survey in the execution of *first-order leveling.* It is a *dumpy level,* constructed of *invar,* binocular in design, having the *spirit level* placed in the tube of the main *telescope,* quite close to the *line of collimation.* The main *telescope* is on the right. A suitable arrangement of mirror and prisms brings an image of the bubble to the left-hand eyepiece. The *telescope* is so mounted that, by means of a micrometer screw, its inclination can be changed through a small *angle* without altering its *elevation.*

In use, the observer sights the rod with the right eye, and at the same time views the bubble with the left eye. By means of the micrometer screw, the inclination of the *telescope* is changed until the bubble is seen in the middle of its tube; the rod is read with the bubble in the mean position. The *collimation error,* made quite small by instrumental adjustment, is then determined, and a *correction* is applied to eliminate its effect from the results. An *invar* rod is used, and the effects of rod temperature and index error considered. In the computations, allowance is made for curvature of the earth and *atmospheric refraction.* The Fischer level was designed by E. G. Fischer, formerly Chief of the Instrument Division, U. S. Coast and Geodetic Survey, and adopted by that Bureau in 1899. The use of *invar* in its construction is of more recent date.

leveling instrument: Gravatt level.—A *dumpy level* with the *spirit level* mounted on top of a short *telescope* tube having a large object glass. Later made with wyes.

This is said to be the original *dumpy level,* which is also claimed for the *Troughton level.*

leveling instrument: hand level.—A small leveling instrument in which the *spirit level* is so mounted that the observer may view the bubble at the same time that he observes an object through the *telescope.*

The instrument is held in the hand when in use, and the viewing of the bubble is accomplished by means of a prism or mirror in the *telescope* tube. The instrument is used in *reconnaissance surveys,* and in cross-section and other work where a high degree of *precision* and *accuracy* is not required.

leveling instrument: Lenoir level.—An instrument which has the *telescope* passing through steel blocks, one near each end, whose upper and lower faces are plane and closely parallel: the lower faces rest upon a brass circle; the upper faces support a spirit level, which is reversed in leveling the instrument.

leveling instrument: Locke hand level.—The generally known design of a *hand level.*

leveling instrument: precise level.—A leveling instrument for use where results of a high order of *accuracy* and *precision* are required. See *leveling instrument: first-order level.*

leveling instrument: Stampfer level.—A name given a type of leveling instrument having the *telescope* tube so mounted that it could be moved in a *vertical plane* about a horizontal axis, involving the use of a *striding level* and a micrometer screw. This type of instrument was also termed a Vienna level.

The mechanical principle involved was apparently quite similar to that of the present-day *first-order level.* See *leveling instrument: Fischer level.*

leveling instrument: Troughton level.—An English instrument having the *spirit level* permanently attached to the top of the telescope tube.

This is said to be the original *dumpy level,* which is also claimed for the *Gravatt level.*

leveling instrument: U. S. Geological Survey level.—A level of the dumpy type, constructed of stainless steel. It has an internal-focusing *telescope;* the level bubble is centered by the end-coincidence method, effected with the aid of a prism device and stellite mirror which can be adjusted by the observer.

This instrument is used by the U. S. Geological Survey in *second-* and *third-order leveling.* By substituting a more sensitive *spirit level* and a more powerful eyepiece for the regular equipment, it may be used for *first-order work.* The interval between *stadia* wires is such that the half-interval intercept on the rod, multiplied by 1,000, will give the distance to the rod in feet.

leveling instrument: wye (Y) level.—A leveling instrument having the *telescope* with attached *spirit level* supported in wyes (Y's), in which it may be rotated about its longitudinal axis (*collimation axis*), and from which it may be lifted and reversed, end for end.

The instrumental adjustments made possible by this mounting are peculiar to the instrument. It forms one of two general classes of leveling instruments, the other class being represented by the *dumpy level.*

leveling of high precision.—See under *leveling: first-order leveling.*

leveling rod (general).—A straight rod or bar, designed for use in measuring a vertical distance between a point on the ground and the *line of collimation* of a leveling instrument which has been adjusted to a horizontal position.

A leveling rod is usually of wood, and has a flat face which is graduated in terms of some linear unit and fractions thereof, the zero of the *graduations* being at one end of the rod. Some rods have the *graduations* on a metal face (*invar* rod). On some rods the *graduation* marks are designed to be read by the observer at the leveling instrument: such a rod is termed a speaking rod or self-reading rod. Another type of rod, called a target rod, carries a target which is moved into position by the rodman in accordance with signals given by the man at the instrument: when the target is bisected by the *line of collimation,* it is read by the rodman. There are many different designs of rods, which will be found defined under leveling rod, followed by the identifying name of the rod.

leveling rod: Barlow.—A *speaking rod* marked with triangles each 0.02 foot in height.

leveling rod: Boston.—A two-piece rod with fixed target on one end.

The target is adjusted in *elevation* by moving one part of the rod on the other. Read by *vernier.*

For heights greater than 5½ feet, the target end is up; for lesser heights, the target end is down. It is a little-used rod.

leveling rod: Conybeare.—A *speaking rod* having tenth-of-foot *divisions,* alternately black and white, each *division* having on it three hexagons in the contrasting color, white or black.

leveling rod: Gravatt.—A *speaking rod,* marked with rectangles each 0.01 foot high, the rectangles at the tenths of foot being longer, and those at the half-tenths being identified by dots.

leveling rod: invar.—A *leveling rod* having the *graduations* painted on a strip of *invar.*

The strip of *invar* is set into the face of the wooden rod, firmly attached to the bottom of the rod (rod shoe), and held in place by guides and by a tension spring at the top of the rod. Invar rods are used in *first-order leveling.*

leveling rod: Molitor precise.—A *speaking rod* of T-shaped cross section, with *graduation* marks shaped as triangles and rectangles, the smallest division being 2 millimeters.

Read by estimation to single millimeters. Equipped with thermometer and *circular level.*

leveling rod: New York.—A two-piece rod with movable target.

For heights greater than 6½ feet, the target is clamped at 6½ feet and raised by extending the rod. Graduated to hundredths of a foot and read by *vernier* to thousandths.

leveling rod: Pemberton.—A *speaking rod* marked with alternate rows of circular and diamond-shaped dots, running diagonally across the rod.

Read to hundredths of a foot.

leveling rod: Philadelphia.—A two-piece *target rod,* with *graduation* marks so styled that it may also be used as a *speaking rod.*

For heights greater than 7 feet the target is clamped at 7 feet, and raised by extending the rod. As a *target rod* it is read by *vernier* to thousandths of a foot; as a *speaking rod,* to half-hundredths.

leveling rod: self-reading or speaking.—See under *leveling rod (general).*

leveling rod: Stephenson.—A *speaking rod* having *graduations* forming a diagonal scale, with horizontal lines through the tenth-of-foot marks.

This rod is read to hundredths of a foot.

leveling rod: target.—See under *leveling rod (general).*

leveling rod: U. S. Coast and Geodetic Survey first-order.—Adopted in 1916, the rod now used in *first-* and *second-order leveling* is a *speaking rod* having a strip of *invar* set in one face, and held in place by a tension spring at the top of the strip, its bottom being firmly attached to the shoe of the rod. The *invar* strip carries centimeter *divisions,* alternately black and white, and is read by estimation to millimeters. The back side of the rod is graduated in feet and tenths. It is equipped with thermometer and *circular level.* Sometimes called an *invar rod.*

leveling rod: U. S. Coast and Geodetic Survey rods.—*Leveling rods* used in the execution of *first-order* (formerly *precise*) and *second-order* (formerly *primary*) *leveling,* before 1895. A *target rod* having *graduations* on a metal strip about 3 meters long set in a wooden rod of plus-sign (+) cross section, the lower end of the strip firmly attached to the wooden rod, the upper end free to respond to changes of temperature. Pointings made on target equipped with small metal scale.

About 1894, a rod of plus-sign (+) cross section was constructed, having *graduation* marks painted to show 1-centimeter intervals, brass plugs being set at 2-centimeter intervals. The rod carried a target and was read to millimeters by means of a 2-centimeter scale. It was equipped with a thermometer and a *circular level.* This rod was replaced with a *speaking rod* of plus-sign (+) cross section, having painted on it *graduation* marks of 1 centimeter, read by estimation to millimeters. Two metal plugs set in the rod 3 meters apart were used in its standardization. It was equipped with thermometer and *circular level.* In 1916 the rod now in use was adopted. See under *leveling rod: U. S. Coast and Geodetic Survey first-order leveling rod.*

leveling rod: U. S. Engineer precise.—A *speaking rod* of T-shaped cross section, 12 feet long, graduated in centimeters.

leveling rod: U. S. Geological Survey precise.—1. A *speaking rod* graduated in *yards* and fractions of a *yard.* It is read for each of three cross wires to the nearest thousandth of a yard. The sum of the three readings is then the mean reading in feet to the nearest thousandth. 2. A *target rod* of plus-sign (+) cross section, a little over 12 feet in length.

There are two forms of this rod: the single-target rod, having *graduations* on one face only; and the double-target rod, with *graduations* on two opposite faces.

line of apsides.—The major axis of an elliptical orbit extended indefinitely in both directions.

line of collimation.—See under *collimation.*

line of levels.—A continuous series of measured differences of elevation. The individual measured differences may be single observations in the case of single-run leveling or the means of repeated observations in the case of double-run leveling.

line of levels: spur.—A *line of levels* run as a branch from the main line of levels, either for the purpose of determining the *elevations* of marks not conveniently reached by the main line of levels or to connect with *tidal bench marks* or other previously established *bench marks* in obtaining checks on old leveling either at the beginning or end of a line of levels or at intermediate junctions along the new line of levels.

line of position.—Any line on which a position is known to be located. A *Sumner line.*

Line of position or position line is a more general term than *Sumner line,* which it includes.

line of sight.—See under *collimation: line of collimation.*

line tree (United States public-land surveys).*—A tree intersected by a surveyed line on which legal *corners* are established, and reported in the field notes of the survey. Also termed a sight tree, fore-and-aft tree.

lines on a spheroid.—See under *spheroid.*

link.—A *unit* of linear measure, one one-hundredth of a *chain,* and equivalent to 7.92 inches.

See under *chain: Gunter's chain.*

link (leveling).—A line, a part of a line, or a combination of lines or parts of *lines of levels,* which, taken as a unit, make a continuous piece of leveling directly from one *junction bench mark* to another junction bench mark without passing through or over any other junction bench marks.

link of levels.—See *link (leveling).*

local adjustment.—See under *adjustment: station adjustment.*

local apparent time.—See under *time.*

local mean time.—See under *time.*

local sidereal time.—See under *time.*

location survey.—See under *survey.*

Locke hand level.—See under *leveling instrument.*

long chord.—The chord which extends from the point of curvature to the point of tangency. See under *curve: point of curvature; point of tangency.*

In descriptions of a circular land boundary, the length and bearing of the long chord is an important feature.

longitude (general).—A coordinate distance, linear or angular, from a north-south reference line.

longitude: astronomic.—The *angle* between the plane of the *celestial meridian* and the plane of an initial *meridian,* arbitrarily chosen.

Astronomic longitude is the *longitude* which results directly from observations on celestial bodies, uncorrected for *deflection of the vertical,* the *prime vertical* component of which, in the United States, may amount to more than 18″. Astronomic longitude is measured by the *angle* at the celestial pole between the tangents to the local and the initial *meridians,* or by the *arc* intercepted on the *equator* by those *meridians.* At an international convention held in Washington, D. C., in 1884, the *Meridian of Greenwich* was adopted as the initial or *prime meridian* for all *longitudes,* and is now generally so used. An expression of longitude is sometimes accompanied by a statement of the method used in its determination, often in adjective form, as "wireless longitude." This may serve as an indication of its *precision.* Among the various methods used are the following:

celestial signals.—The local *time* at the new station of the occurrence of celestial phenomena is compared with the corresponding *time* of the occurrence at a base station. Among such phenomena are *eclipses* of the Moon, *eclipses* of Jupiter's satellites, *occultations* of stars, etc.

chronometric.—The local *time* at the new station is compared with the *time* at a base station by transporting *chronometers* from one station to the other.

lunar-distance, moon-altitude, moon-culmination, etc.—The local *time* at the new station is compared with the *time* at a base station, both *times* being determined from the position of the moon relative to other celestial bodies.

telegraphic.—The local *time* at the new station is compared with the *time* at a base station by means of the electric-telegraph land-lines and sea cables.

terrestrial signals.—Local *times* noted at new and base stations of the occurrence of such signals as a flash of gunpowder.

wireless.—The local *time* at the new station is compared with the *time* at a base station by means of radio.

longitude: celestial.—The *arc* of the *ecliptic* intercepted between the *vernal equinox* and the foot of a *great circle* perpendicular to the *ecliptic* and passing through the object whose *longitude* is to be defined.

Celestial longitude is measured along the *ecliptic* from west to east. It is not the same as *astronomic longitude* and does not enter into usual problems of *surveying.*

longitude: geodetic.—The *angle* between the plane of the *geodetic meridian* and the plane of an initial *meridian,* arbitrarily chosen.

A geodetic longitude may be measured by the *angle* at the pole of revolution of the *spheroid* between the local and initial *meridians,* or by the *arc* of the *geodetic equator* intercepted by those *meridians.* In the United States, geodetic longitudes are numbered from the *Meridian of Greenwich,* but are computed from the *meridian* of station Meades Ranch as prescribed in the *North American datum of 1927.* In recording *geodetic position* it is essential that the *geodetic datum* on which it is based also be stated. A geodetic longitude differs from the corresponding *astronomic longitude* by the amount of the *prime-vertical* component of the local *deflection of the vertical* divided by the cosine of the *latitude.* In this country, this may amount to as much as 26″.

longitude: geographic.—A general term, applying alike to *astronomic* and to *geodetic longitudes.*

longitude equation.—See under *equation.*

longitude signal.—See under *signal.*

longitude term.—See under *gravity formula.*

loran.—A pulse-type electronic navigation system for measuring distance differences with respect to fixed transmitters of known geographic position.

A loran receiver may be located on a particular hyperbola by measuring the difference in arrival times of pulses sent in a synchronous manner from a single pair of loran transmitters. The receiver may also be located on another hyperbola by a similar time measurement relative to another pair of transmitters. Intersection of the hyperbolas fixes the location of the receiving point. Loran fixes may be obtained at a range of 750 nautical miles in daylight and 1,400 nautical miles at night, and are very nearly independent of weather conditions. The *precision* of a loran *fix* is comparable to that obtained by high grade celestial observations with a *sextant.*

lost corner (United States public-land surveys).—See under *corner.*

lower culmination.—See under *culmination.*

low-water line.—The line defined by the boundary of a body of water at its lowest stage (elevation).

As there may be appreciable variation with time in the elevation of the low-water surface at a designated locality, a mean value of the low-water elevation should be used in determining the ground position of the low-water line. See *mean low water.*

loxodrome: loxodromic curve.—See under *rhumb line.*

lunar month.—See under *month.*

lunation.—See under *month: synodical month.*

Luzon datum.—See under *datum.*

M

magnetic chart.—See under *chart.*

magnetic declination.—The *bearing* (reckoned east or west from the north branch of the celestial meridian plane) of magnetic north as determined by the positive pole of a freely suspended magnetic needle which is subject to no transient artificial disturbance.

In nautical and aeronautical navigation the term *variation* is used instead of *declination,* and the *angle* is called variation of the compass or *magnetic variation.*

magnetic variation.*—Regular or irregular change with time of *magnetic declination,* dip, or intensity.

In nautical and aeronautical navigation, and in some localities *surveying,* the term variation is used instead of, and meaning, *magnetic declination.* The regular variations are secular, the change from year to year which usually extends for many decades in the same direction; annual, having a period of one *year;* and diurnal, having a daily period. The irregular variations are known, when severe, as magnetic storms. Locally the magnetic field may be affected by direct-current electricity and other artificial disturbances. It was once a common practice of surveyors to denote as variation the net amount by which the compass departed from the direction taken as north in the description of a particular line, even when this was known to be slightly at variance with the *celestial meridian*.

main-scheme station.—See under *station: principal station*.

manometer.—A gage for measuring the pressure of a gas.

In observing the *Mendenhall pendulum*, the *receiver* in which it is swung is exhausted of air to a prescribed maximum pressure. A manometer composed of a U-shaped tube, closed at one end and containing mercury, is placed in the *receiver* to register the air pressure.

map.*—A representation on a plane surface, at an established *scale*, of the physical features (natural, artificial, or both) of a part or the whole of the earth's surface, by means of signs and symbols, and with the means of *orientation* indicated. Also a similar representation of the heavenly bodies.

A map may emphasize, generalize, or omit the representation of certain features to satisfy specific requirements. The type of information which a map is designed primarily to convey is frequently used, in adjective form, to distinguish it from maps of other types. A map should carry a record of the *projection* upon which it is constructed.

map: aerial.—See under *chart: aeronautical chart*.

map: aerial navigation.—See under *chart: aeronautical chart*.

map: air navigation.—See under *chart: aeronautical chart*.

map: aviation.—See under *chart: aeronautical chart*.

map: base.*—A map on which information may be placed for purposes of comparison or geographical correlation.

The term base map was at one time applied to a class of *maps* now known as *outline maps*. It may be applied to *topographic maps*, also termed mother maps, which are used in the construction of many types of *maps* by the addition of particular data.

map: bus and truck.*—A *special-purpose map* showing routes used or suitable for use in commercial transportation by motor vehicles.

map: cadastral.*—A *map* showing the boundaries of subdivisions of land, usually with the bearings and lengths thereof and the areas of individual tracts, for purposes of describing and recording ownership.

A cadastral map may also show culture, drainage, and other features relating to the value and use of land.

map: compiled.*—A *map* incorporating information collected from various sources, not developed by *surveys* made for the special purpose of the *map* in question.

Most *small-scale maps* of large areas are compiled.

map: composite.*—A *map* which portrays information of two or more general types.

A composite map is usually a *compiled map*, bringing together on one *map*, for purposes of comparison, data which were originally portrayed on separate *maps*.

map: contour.*—A *topographic map* which portrays relief by means of *contour lines*.

The form "contoured map" is disapproved.

map: county.*—A *map* of the area of a county as a unit.

map: distribution.*—A *map* which shows the *geographic* arrangement of a specific product, commodity, or formation.

Distribution maps may be nonquantitative or quantitative. Nonquantitative distribution maps may be simple, compound, dominant, etc., depending upon the character of the detail portrayed. Quantitative distribution is statistical in character.

map: dynamic.*—A map designed to show motion, action, or change.

A dynamic map involves an element of *time*. The term may be applied to *maps* depicting traffic flow, migration, military movement, progress in an engineering project, historical geography, etc. Various symbols, such as flow lines and arrows, are employed to depict movement, or a dynamic map may be a composition of two or more *static maps*, depicting comparable data at stated dates or times. A plan of a proposed development is not a *map*. Therefore, the use of the term dynamic map to describe such a plan is disapproved.

map: engineering.*—A *map* showing information that is essential for planning an engineering project or development and for estimating its cost.

An engineering map is usually a large-scale *map* of a comparatively small area or of a route. It may be entirely the product of an engineering survey, or reliable information may be collected from various sources for the purpose and assembled on a *base map*.

map: hemispherical.*—A *map* of one-half of the earth's surface, bounded by the *equator*, or by *meridians*.

The earth is usually considered divided either at the *equator*, into the northern and southern hemispheres, or along some *meridian* between Europe and America and continued around the globe, into eastern and western hemispheres. The division used in *cartography* is usually along the *meridian* of *longitude* 20° west of Greenwich. The Americas are in the Western Hemisphere. The division of the surface of the earth into hemispheres of political significance is not a determined matter.

map: highway.*—A map on which the location of improved roads and highways is shown.

map: hypsographic.*—A *topographic map* on which *elevations* are referred to a *sea-level datum*.

Sometimes called a hypsometric map, the use of which term is disapproved.

map: hypsometric.*—Disapproved. See under *map: hypsographic map*.

map: index.*—A *map* which shows the location of collections of related data, whether in the form of other *maps*, or statistical tables, or descriptive in character.

Index maps may be used to show references to the origin, place of deposit or filing, and other common characteristics (identifying quality) of such data.

map: large scale.—See under *map scale: fractional*.

map: outline.*—A *map* which presents just sufficient geographic information to permit the correlation of additional data placed upon it.

Outline maps correspond to what were at one time known as *base maps*. Outline maps usually show only coast lines, principal rivers, major civil boundaries, and large cities, leaving as much space as possible for the reception of particular data. An outline map presents less detail than a *base map*.

map: planimetric.*—A *map* which presents the horizontal *positions* only for the features represented; distinguished from a *topographic map* by the omission of *relief* in measureable form.

The natural features usually shown on a planimetric map include rivers, lakes, and seas; mountains, valleys, and plains; forests, prairies, marshes, and deserts. The cultural features include cities, farms, transportation routes, and public utility facilities; political and private boundary lines. A planimetric map intended for special use may present only those features which are essential to the purpose to be served.

map: postal.*—Any *special-purpose map* published primarily for the use of the Postal Service.

Postal features are emphasized and the *maps* are composed to show postal information to the best advantage. A list of "Official Postal Maps" is published by the Post Office Department, Washington, D. C.

map: post route.*—Any *postal map* of a State, Territory, or island possession of the United States, published by the Post Office Department.

Each post route map shows all post offices within the area which it represents, indicates the method and frequency of mail supply, and gives intermediate distances on mail-supply routes. County boundaries are delineated, and all county names are shown. Also shown are the principal drainage features, but no highways, and only those railroads which carry mail.

map: reconnaissance.*—A *map* incorporating the information obtained in a *reconnaissance survey,* and data obtained from other sources.

A reconnaissance map differs from a *map* based on an *exploratory survey* by providing greater detail, selected to serve a special or general purpose. See also *reconnaissance sketch.*

map: rural delivery.*—A *postal map* of a county or locality on which roads travelled by rural carriers are distinguished, and on which are shown the location of post offices, houses, schools, and churches at the time the *map* was drawn.

Rural delivery maps are on a *scale* of about 1 *inch* equals 1 *mile,* and are divided into two groups: *county maps* and local *maps.* Where much of the area of a county is covered by rural-delivery service and adequate survey data are available, a *county map* is prepared showing all routes served from the post offices within the county. Where no *county map* has been prepared, a local *map* is constructed for each post office and the area which it serves.

map: school and bus.*—A *map* showing schools and the routes of busses serving them.

map: small scale.—See under *map scale: fractional.*

map: special-purpose.*—Any *map* designed primarily to meet specific requirements.

Usually the *map* information portrayed on a special-purpose map is emphasized by omitting or subordinating other information of a general character which is not essential or is of less importance to the purpose to be served. The special purposes for which *maps* are designed and used are numerous and are increasing with the trend toward the graphic portrayal of factual information in relation to the areas of origin or application. The *map,* in most cases, serves as a base on which special information is correlated. A word or phrase is usually employed to describe the type of information which a *map* is designed to present, whether for general or special use. Definitions for a number of special-purpose maps will be found under their specific names.

map: State.*—A *map* of the area of a State as a unit.

map: State base.*—A *base map* of the area of a State as the unit.

Emphasizing no one type of information, such a *map* is suitable for overprinting information for special purposes. The term is frequently used to describe *State maps* that are issued by agencies of the Federal Government, which are not copyrighted, and are used by government and private agencies as bases on which to portray special information.

map: static.*—A *map* that portrays information as of a single date or time.

Most *maps* are static maps, presenting information as of a given date. Static maps presenting comparable data as of different dates may be combined into a *dynamic map.*

map: topographic.*—A *map* which presents the horizontal and vertical *positions* of the features represented; distinguished from a *planimetric map* by the addition of *relief* in measurable form.

A topographic map usually shows the same features as a *planimetric map,* but uses contours or comparable symbols to show mountains, valleys, and plains; and, in the case of hydrographic charts, symbols and numbers to show depths in bodies of water.

map: Topographic Map of the United States.*—The recommended designation for the *topographic map* of the United States being prepared of quadrangle areas in atlas sheet form, chiefly by the United States Geological Survey.

This *map* portrays all basic information about location, *elevation,* and extent of physical and cultural features that are required for preliminary economic and engineering studies, and for incorporation in a base for *maps* prepared for special purposes. The use of various other terms which have been applied to this map is disapproved. These include the following: standard topographic map of the United States; general base map; general topographic map; general utility map; general utility map of the United States; general utility topographic map of the United States; and possibly others.

map: Transportation Map of the United States.*—The official designation of the *map* which is being prepared (1942) for the Public Roads Administration by the United States Geological Survey, on which are shown, as of a specified date, all improved transportation routes in the United States, including highways, railroads, air, and inland water routes.

The *map* will consist of 438 regular sheets, 26 by 36 *inches* in size, *scale* 1 : 250,000 (approximately 1 *inch* to 4 *miles*), and of special *maps* of large cities, *scale* 1 : 125,000, which may be published as separate sheets or as inserts on the regular sheets. The designation general highway and transportation map, which has been used for this *map,* is disapproved.

map projection (general).—An orderly system of lines on a plane representing a corresponding system of imaginary lines on an adopted terrestrial or celestial *datum* surface. Also the mathematical concept of such a system.

For *maps* of the earth, a projection consists of a network (*graticule*) of lines representing parallels of *latitude* and meridians of *longitude,* or of a *grid* based on such *parallels* and *meridians.* A map projection may be derived by geometrical construction or by mathematical analysis. The mathematical concept of map projection is the mathematical principle upon which it is based, expressed as formulas for computing the elements of the *projection* and tables used in constructing its graphical representation (*graticule* or *grid*). *Projections* derived by mathematical analysis are generally used for *maps* constructed with survey data. Map projections vary considerably in their characteristics, according to the qualities which they preserve in the mapping, and the methods by which this is accomplished. They are classified (1) according to the characteristics which they preserve, as *conformal, equal area, azimuthal,* etc.; (2) according to the methods used in their development, as *polyconic, gnomonic, stereographic,* etc.; and (3) according to the names of their authors, often coupled with some characteristic, as *Mercator, Bonne, Lambert with two standard parallels,* etc. The various map projections are defined under their particular designations.

map projection: Aitoff equal-area.—A *Lambert equal-area azimuthal projection* of a hemisphere converted into a *map projection* of the entire sphere by a manipulation suggested by Aitoff. It is a *projection* bounded by an ellipse in which the line representing the *equator* (major axis) is double the length of the line representing the *central meridian* (minor axis).

Tables for constructing this *projection* are prepared arithmetically from the tables for the *Lambert equal-area meridional map projection.*

map projection: Albers conical equal-area.—An *equal-area map projection* of the so-called conical type, on which *geographic meridians* are represented by straight lines which meet at a common point; this common point serves as the center of a series of arcs of circles which represent the *geographic parallels. Meridians* and *parallels* intersect in right angles. Along two selected *parallels,* called *standard parallels,* the *scale* is held exact; along the other *parallels,* the *scale* varies with the *latitude,* but is constant along any given *parallel.* Between the *standard parallels,* the meridional *scale* is too great; beyond them, too small. At any point on the *projection,* the departure from exact *scale* along a *parallel* is of the opposite sign from the departure from exact *scale* along the *meridian,* and the two are so related as to produce an *equal-area map projection.* Passing through every point are two lines of true-length *scale* which intersect in right *angles;* these are called *isoperimetric curves.*

This projection was devised by Dr. H. C. Albers in 1805.

map projection: aphylactic.—A map projection which is neither a *conformal map projection* nor an *equal-area map projection.*

map projection: authalic.—An *equal-area map projection.*

map projection: autogonal.—A *conformal map projection.*

The term autogonal, meaning *conformal,* is seldom used. Its future use should be avoided.

map projection: azimuthal (or zenithal).—A *map projection* on which the *azimuths* or *directions* of all lines radiating from a central point or pole are the same as the *azimuths* or *directions* of the corresponding lines on the sphere.

As a class, azimuthal map projections include a number of special *projections;* these are described under their particular designations. An azimuthal map projection may be constructed having two poles or points, lines from which are shown in correct *azimuth.* Such a projection is termed a *doubly azimuthal map projection.*

map projection: azimuthal equidistant.—An *azimuthal map projection* on which straight lines radiating from the center or pole of *projection* represent *great circles* in their true *azimuths* from that center, and lengths along those lines are of exact *scale.*

This projection is neither *equal-area* nor *conformal.*

map projection: Bonne.—A modified *equal-area map projection* of the so-called conical type, having lines representing a *standard parallel* and a *central meridian* intersecting near the center of the *map.* The line representing the *central meridian* (*geographic*) is straight and the *scale* along it is exact. All *geographic parallels* are represented by *arcs* of concentric circles at their true distances apart, divided to exact *scale,* and all *meridians,* except the central one, are curved lines connecting corresponding points on the *parallels.*

This *projection* is strictly *equal-area.* A particular form of this *projection* is the *Sanson-Flamsteed* or *sinusoidal map projection,* in constructing which the *equator* is used as the *standard parallel.*

map projection: Cassini.—A conventional *map projection* constructed by computing the lengths of arcs along a selected *geographic meridian* and along a *great circle* perpendicular to that *meridian,* and plotting these as *rectangular coordinates* on a plane.

map projection: conformal.—A *map projection* on which the shape of any small area of the surface mapped is preserved unchanged.

Conformal map projections are sometimes termed *orthomorphic map projections,* "orthomorphic" meaning "right-shape"; this is misleading because, if the area mapped is large, its shape will not be preserved, but only the shape of each small section of it. The exact condition for a conformal map projection is that the *scale* at any point be the same in all *directions:* the *scale* may change from point to point, but at each point it will be independent of the *azimuth.* Among the more important conformal map projections are the *Mercator,* the *stereographic,* the *transverse Mercator,* and the *Lambert conformal map projections:* the latter two are used in the *State coordinate systems.*

map projection: conic.—A *map projection* produced by projecting the *geographic meridians* and *parallels* onto a cone which is tangent to (or intersects) the surface of a sphere, and then developing the cone into a plane.

There are several methods of passing from the sphere to the cone, most of which are analytical in character and do not admit of graphical construction. For example: the *Lambert conformal conic map projection.* A *perspective map projection* from the center of the sphere would admit of graphical construction. Conic map projections may be considered as including *cylindrical map projections* when the apex of the cone is at an infinite distance from the sphere, and projections on a tangent plane when that distance is zero. Conic map projections may be illustrated with a single cone which is tangent to the sphere, or which cuts the sphere along two *parallels;* or there may be a series of tangent cones, all with apices on an extension of the axis of the sphere, at constantly increasing (or decreasing) distances from the sphere. While a cone or cones may be used in illustrating the conic map projections, care must be taken not to consider such *projections* as geometrical concepts, which most of them are not.

map projection: cylindrical.—A *map projection* produced by projecting the *geographic meridians* and *parallels* onto a cylinder which is tangent to (or intersects) the surface of a sphere, and then developing the cylinder into a plane.

There are several methods of passing from the sphere to the cylinder. Some of these are analytical in character, and do not permit of graphic construction. For example, the computation of the *Mercator map projection.* Other methods may be defined geometrically, and the *projection* constructed graphically. For example, the *cylindrical equal-spaced map projection.* Both groups of projections are spoken of as cylindrical projections. All of them may be illustrated, and some of them demonstrated, by means of a cylinder tangent to a sphere, cut along an element, and flattened into a plane.

map projection: cylindrical equal-area.—A *cylindrical map projection* upon a cylinder tangent to a sphere, showing the *geographic meridians* as a family of equal-spaced parallel straight lines perpendicular to a second family of parallel straight lines which represent the *geographic parallels,* and which are so spaced as to produce an *equal-area map projection.*

The equal-area condition preserves a constant ratio between corresponding ground and *map* areas. This *projection* must not be confused with the *Mercator projection* to which it bears some general resemblance.

map projection: cylindrical equal-spaced.—A *cylindrical map projection* upon a cylinder tangent to a sphere, showing the *geographic meridians* as a family of equal-spaced parallel straight lines perpendicular to a second family of equal-spaced parallel straight lines which represent the *geographic parallels.*

The spacing of the *parallels* need not be the same as that of the *meridians.*

map projection: doubly azimuthal.—An *azimuthal map projection* having two poles.

map projection: equal-area.—A *map projection* on which a constant ratio of areas is preserved: that is, any given part of the *map* on an equal-area projection bears the same relation to the area on the sphere which it represents as the whole *map* bears to the entire area represented.

On an equal-area map, a definite area such as a square *inch,* will represent a constant area on the sphere, no matter on what part of the *map* the square *inch* is located. Also called an equivalent map projection, equal-area map projections comprise an extensive class of particular projections, some of them of considerable usefulness.

map projection: equivalent.—See under *map projection: equal-area map projection.*

map projection: geometric.—See under *map projection: perspective map projection.*

map projection: globular.—A *map projection* representing a hemisphere, on which the *equator* and a central *geographic meridian* are represented by straight lines intersecting at right *angles;* these lines are divided into equal parts. All *meridians,* except the central one, are represented by circular *arcs* connecting points of equal division on the *equator* with the poles. The *parallels,* except the *equator,* are circular *arcs* dividing the central and extreme outer *meridians* into equal parts. The extreme outer *meridian* limits the *projection* and is a full circle.

map projection: gnomonic.—A *perspective map projection* on a plane tangent to the surface of a sphere, having the point of projection at the center of the sphere.

The *projection* is neither *conformal* nor *equal-area.* It is the only *projection* on which *great circles* on the sphere are represented as straight lines.

map projection: homolographic (homalographic).—An *equal-area map projection.*

This term is found in the designations given some particular *map projections,* such as the *Mollweide homalographic projection.*

map projection: International Map of the World.—A *modified polyconic map projection,* with two *standard meridians* along which the *scale* is held exact. The *scale* of the *map* is 1 : 1,000,000 ; the *geographic meridians* are represented by straight lines connecting corresponding points on the top and bottom *geographic parallel* lines of the *projection* which are truly divided. These lines representing the *parallels* are *arcs* of circles, not concentric.

Up to latitude 60°, each sheet of the International Map of the World includes 4° of *latitude* and 6° of *longitude;* above latitude 60°, the sheets are double width, that is, each covers 4° of *latitude* and 12° of *longitude.* It is also called the millionth scale map of the World. The *projection* was devised by Lallemand in about 1909.

map projection: Lambert azimuthal (polar).—A *Lambert equal-area map projection* with the pole of projection at the pole of the sphere, and the radii of the circles which represent the *geographic parallels* corresponding to the chords of those *parallels.*

map projection: Lambert central equivalent map projection upon the plane of the meridian.—See under *map projection: Lambert zenithal (azimuthal) equal-area.*

map projection: Lambert conformal conic.—A *conformal map projection* of the so-called conical type, on which all *geographic meridians* are represented by straight lines which meet in a common point outside the limits of the *map,* and the *geographic parallels* are represented by a series of arcs of circles having this common point for a center. *Meridians* and *parallels* intersect in right *angles,* and *angles* on the earth are correctly represented on the *projection.* This *projection* may have one *standard parallel* along which the *scale* is held exact; or there may be two such *standard parallels,* both maintaining exact scale. At any point on the *map,* the *scale* is the same in every direction. It changes along the *meridians,* and is constant along each *parallel.* Where there are two *standard parallels,* the *scale* between those *parallels* is too small; beyond them, too large.

The Lambert conformal conic map projection with two *standard parallels* is the base for the *State coordinate systems* devised by the U. S. Coast and Geodetic Survey for zones of limited north-south dimension, and indefinite east-west dimension. In those systems, the *standard parallels* are placed at distances of one-sixth the width (north-south) of the *map* from its upper and lower limits.

map projection: Lambert equal-area meridional.—See under *map projection: Lambert zenithal (azimuthal) equal-area.*

map projection: Lambert zenithal (azimuthal) equal-area.—An *azimuthal map projection* having the pole of the *projection* at the center of the area mapped. The *azimuths* of *great circles* radiating from this center (pole) are truly represented on the *map;* equal distances on those *great circles* are represented by equal linear distances on the *map,* but the *scale* along those *great circle* lines so varies with distance from the pole of the *projection,* that an *equal-area projection* is produced.

When the pole of the *projection* is on the *equator,* the *projection* is called the Lambert central equivalent projection upon the plane of the meridian; also, the Lambert equal-area meridional projection.

map projection: Mercator.—A *conformal map projection* of the so-called cylindrical type. The *equator* is represented by a straight line true to *scale;* the *geographic meridians* are represented by parallel straight lines perpendicular to the line representing the *equator;* they are spaced according to their distance apart at the *equator.* The *geographic parallels* are represented by a second system of straight lines perpendicular to the family of lines representing the *meridians,* and therefore parallel with the *equator. Conformality* is achieved by mathematical analysis, the spacing of the *parallels* being increased with increasing distance from the *equator* to conform with the expanding *scale* along the *parallels* resulting from the *meridians* being represented by parallel lines.

The Mercator map projection is considered one of the most valuable of all *map projections*, its most useful feature being that a line of constant *bearing* (*azimuth*) on a sphere is represented on the *projection* by a straight line. It is not a perspective *projection* on a cylinder, and is not developed geometrically.

map projection: Mercator equal-area.—The *sinusoidal map projection.*

map projection: Mercator, transverse.—See under *map projection: transverse Mercator map projection.*

map projection: meridional orthographic.—See under *map projection: orthographic map projection.*

map projection: millionth-scale map of the World projection.—See under *map projection: International Map of the World projection.*

map projection: modified polyconic.—A *map projection* obtained from the regular *polyconic projection* by so altering the *scale* along the central *meridian* that the *scale* is exact along two *standard meridians*, one on either side of the *central meridian* and equidistant therefrom. Also a *rectangular polyconic map projection.*

A modified polyconic map projection is used for the *International Map of the World*, the *scale* being exact along *meridians* located 2° from the *central meridian*. A modified polyconic map projection is also used for some State maps published by the U. S. Geological Survey.

map projection: Mollweide homalographic.—An *equal-area map projection* showing the *equator* and *geographic parallels* as straight lines, and the *geographic meridians* as elliptical *arcs*, with the exception of the *central meridian*, represented by a straight line, and the *meridian* 90° from the center, shown as a full circle.

This *projection* is used to show the entire surface of the earth, in which case it is bounded by an ellipse whose major axis, representing 360° of *longitude*, is double the length of its minor axis, representing 180° of *latitude*. It is also used to map a hemisphere, when the boundary of the *projection* will be a full circle.

map projection: orthembadic.—An *equal-area map projection.*

map projection: orthographic.—A *map projection* produced by straight parallel lines through points on the sphere and perpendicular to the plane of the *projection.*

The orthographic map projection corresponds to a *perspective projection* with the point of projection at an infinite distance from the sphere. As used for *maps* of the earth, this *projection* is classified as (a) a polar orthographic map projection, having the plane of the projection perpendicular to the axis of *rotation* of the earth (parallel with the plane of the *equator*); in this *projection*, the *geographic parallels* are full circles, true to *scale*, and the *geographic meridians* are straight lines; (b) the meridional orthographic map projection, having the plane of the projection parallel to the plane of some selected *meridian*; the *geographic parallels* and the central *meridian* are straight lines, the outer *meridian* is a full circle, and the other *meridians* are arcs of ellipses.

map projection: orthomorphic.—A *conformal map projection.*

Orthomorphic is a little-used term, meaning "right-shape."

map projection: perspective.—A *map projection* produced by straight lines radiating from a selected point and passing through points on the sphere to the plane of projection. Sometimes called a geometric projection.

The plane of projection is usually tangent to the sphere which represents the earth at the center of the area being mapped; the point of projection is on the diameter of the sphere which passes through the point of tangency, and at some selected point on that diameter. If the point of projection is at the center of the sphere, there results the *gnomonic map projection*; if at the opposite end of the diameter from the point of tangency of the plane of projection, it becomes a *stereographic map projection;* if at an infinite distance, an *orthographic map projection.*

map projection: perspective map projection upon a tangent cylinder.—A *cylindrical map projection* upon a cylinder tangent to a sphere, by means of straight lines radiating from the center of the sphere.

The *geographic meridians* are represented by a family of equally spaced parallel straight lines, perpendicular to a second family of parallel straight lines which represent the *geographic parallels*. The spacing, with respect to the *equator*, of the lines which represent the *parallels*, increases as the tangent of the *latitude*; the line representing 90° *latitude* is at an infinite distance from the line which represents the *equator*. This *projection* must not be confused with the *Mercator projection* to which it bears some general resemblance.

map projection: polar orthographic.—See under *map projection: orthographic map projection.*

map projection: polyconic.—A *map projection* having the central *geographic meridian* represented by a straight line, along which the spacing for lines representing the *geographic parallels* is proportional to the distances apart of the *parallels*; the *parallels* are represented by *arcs* of circles which are not concentric, but whose centers lie on the line representing the central *meridian*, and whose radii are determined by the lengths of the elements of cones which are tangent along the *parallels*. All *meridians* except the central one are curved.

This *projection* is neither *conformal* nor *equal-area*, but it has been much used for *maps* of small areas because of the ease with which it can be constructed. It is the *map projection* used for the *Topographic Map of the United States* (U. S. Geological Survey), and in a modified form is used for *maps* of large areas. It was devised by F. R. Hassler, organizer and first superintendent of the U. S. Coast Survey (now the U. S. Coast and Geodetic Survey).

map projection: polyconic, modified.—See under *map projection: modified polyconic map projection.*

map projection: polyconic, rectangular.—See under *map projection: rectangular polyconic map projection.*

map projection: polyconic, transverse.—See under *map projection: transverse polyconic map projection.*

map projection: rectangular polyconic.—A modified *polyconic map projection* having a line representing a *standard parallel* divided to exact *scale*, through whose division points pass the lines representing the *geographic meridians*, intersecting the lines which represent the *geographic parallels* in right *angles.*

map projection: Sanson-Flamsteed.—The *sinusoidal map projection.*

map projection: sinusoidal.—A particular type of the *Bonne map projection*, employing the *equator* as the *standard parallel*, and showing all *geographic paral-*

lels as truly spaced parallel straight lines, along which exact *scale* is preserved.

This is an *equal-area map projection.* It is also known as the *Mercator equal-area map projection* and as the Sanson-Flamsteed map projection. It was employed in the Mercator-Hondius atlases as early as 1606.

map projection: stereographic.—A *perspective map projection* having the point of projection at the opposite end of the diameter of the sphere from the point of tangency of the plane of projection.

It is *conformal,* and is the only *azimuthal map projection* having that quality. It is one of the most widely known of all *map projections,* and has been much used for *maps* of a hemisphere. When the center of the projection is located at a pole of the sphere, it is called a stereographic polar projection; when on the *equator,* a stereographic meridional projection; and when on some other selected *parallel* of *latitude,* a stereographic horizon projection. The stereographic map projection dates back to the days of ancient Greece, having been used by Hipparchus (160–125 B. C.).

map projection: transverse Mercator.—A *map projection* of the so-called cylindrical type, being in principle equivalent to the regular *Mercator map projection* turned (transversed) 90° in azimuth.

In this *projection,* the *central meridian* is represented by a straight line, corresponding to the line which represents the *equator* on the regular *Mercator map projection.* Neither the *geographic meridians,* except the central *meridian,* nor the *geodetic parallels,* except the *equator* (if shown) are represented by straight lines. It is a *conformal projection,* and is the base used in the *State plane-coordinate systems* for the *grids* of those zones whose greater dimension is in a north-and-south direction.

map projection: transverse polyconic.—A *polyconic map projection* which is turned (transversed) 90° in *azimuth* by substituting for the *central meridian,* a *great circle* perpendicular to the *geographic meridian* to provide a control axis for the *projection,* along which axis will lie the centers of the circular *arcs* representing lines of tangency of cones with the surface of the sphere.

This is a difficult projection to construct, but it is useful in showing, with comparatively small distortion, a narrow area of large east-and-west dimension.

map projection: Werner.—A particular case of the *Bonne map projection,* in which the *standard parallel* is at the pole, and the tangent cone becomes a tangent plane.

Any one *geographic meridian* is chosen as the *central meridian* and represented by a straight line, divided to exact *scale.* The *geographic parallels* are represented by circular *arcs,* also divided to exact *scale,* and the other *meridians* are curved lines.

map scale.*—The relationship which exists between a distance on a *map* and the corresponding distance on the earth.

A map scale may be expressed as an equivalence, as a numerical fraction or ratio, or shown graphically. On large-scale *maps,* the distance on the earth is on a designated *datum,* as *sea level* or ground level.

map scale: equivalent.*—An equivalent scale is the relationship which a small distance on the *map* bears to the corresponding distance on the earth, expressed as an equivalence.

Usually, but not necessarily, the equivalence is expressed in different specified units; for example, 1 *inch* (on the *map*) equals 1 *mile* (on the ground). Of the abbreviated forms, "*inch* to the *mile*" and "*mile* to the *inch,*" the former is preferred. Infrequently called verbal scale.

map scale: fractional.*—A fractional scale is the ratio which any small distance on the *map* bears to the corresponding distance on the earth.

It may be written in the form of a fraction: 1/10,000; or as a proportion, 1:10,000. Very infrequently called numerical scale, natural scale, and linear scale. These terms are not recommended.

Fractional scales are representative in any linear units. Usually the term representative fraction, however, is applied to a fractional scale whose numerator is unity (1) and is frequently referred to as the "R. F." of the *map.*

For a map of large scale, the representative fraction has a small denominator; for a map of small scale, the representative fraction has a large denominator.

map scale: graphic (or bar).*—A line on a *map* subdivided and marked with the distance which each of its parts represents on the earth.

mapping plan: national.—A program for the completion of the *Topographic Map of the United States.*

The Federal Board of Surveys and Maps in 1934 and again in 1936 adopted plans which proposed a time schedule for the completion of the *control surveys* and topographic mapping of the United States, and a fiscal budget for those operations. The *Temple Act* (H. R. 4522, 68th Congress), approved 1925, was the forerunner of the various national mapping plans.

mean: arithmetical.—See under *arithmetical mean.*

mean: weighted.—See under *weighted mean.*

mean error.—See under *error.*

mean high water.—The mean height of all *high waters* at a particular point or station over a considerable period of time.

For tidal waters, the cycle of change covers a period of about 18.6 years, and the mean high water is the mean of all *high waters* for that period. For any body of water, it is the mean of all *high waters* over a period of time of such length that increasing its length does not appreciably change the mean.

mean low water.—The mean height of all *low waters* at a particular point or station over a considerable period of time.

For tidal waters, the cycle of change covers a period of about 18.6 *years,* and the mean low water is the mean of all *low waters* for that period. For any body of water, it is the mean of all *low waters* over a period of time of such length that increasing its length does not appreciably change the mean.

mean of the errors.—See under *error.*

mean sea level.—The average height of the sea for all stages of the tide.

Mean sea level is obtained by averaging observed hourly heights of the sea on the open coast or in adjacent waters having free access to the sea, the average being taken over a considerable period of time.

mean solar day.—See under *day.*

mean solar time.—See under *time.*

mean-square error.—See under *error.*

mean sun.—See under *time: mean solar time.*

meander line (United States public-land surveys).*—A *traverse* of the margin of a body of water.

Meander lines are not run as *boundary lines,* but are run for the purpose of defining the sinuosities of the bank or shore line, and for ascertaining the quantity of land remaining after segregation of the water area. In General Land Office practice, only permanent natural bodies of water are meandered.

memorial (United States public-land surveys).*—A durable article deposited in the ground at the position of a *corner,* to perpetuate that position should the *monument* be removed or destroyed.

The memorial is usually deposited at the base of the *monument* and may consist of anything durable, such as glass or stoneware, a marked stone, charred stake, or quantity of charcoal.

Mendenhall pendulum.—See under *pendulum.*

Mercator bearing.—The *bearing* of a straight line plotted on a Mercator *chart* as taken from the *chart.*

It is the *angle* between the straight line and the chart meridians.

Mercator equal-area map projection.—See under *map projection.*

Mercator map projection.—See under *map projection.*

Mercator map projection, transverse.—See under *map projection.*

Mercator track.—A *rhumb line* on a *map* or *chart* constructed on a *Mercator map projection.*

mercury barometer.—See under *barometer.*

meridian (general).—A north-south line from which *longitudes* (or *departures*) and *azimuths* are reckoned; or a plane, normal to the *geoid* or *spheroid,* defining such a line.

meridian: astronomic.—A line on the surface of the earth having the same *astronomic longitude* at every point.

Because the *deflection of the vertical* is not the same at all points, an astronomic meridian is an irregular line, not lying in a single plane. The astronomic meridian and the line whose *astronomic azimuth* at every point is south or north (0° or 180°) are not necessarily coincident, although in *land surveying* the term astronomic meridian is sometimes applied to the north-south line which has its initial on a prescribed astronomic meridian.

meridian: auxiliary guide (United States public-land surveys).*—A new *guide meridian* established, when required, for control purposes where the original *guide meridians* were placed at greater intervals than 24 miles.

Auxiliary guide meridians may be required to limit *errors* of old or to control new surveys; they are surveyed in all respects like regular *guide meridians,* and may be assigned a local name, as "Grass Valley Guide Meridian," or "Twelfth Auxiliary Guide Meridian West."

meridian: celestial.—The *hour circle* which contains the *zenith.* Also defined as the *vertical circle* which contains the celestial pole.

The plane of the celestial meridian is parallel with, but, due to the *deflection of the plumb line,* usually does not contain the axis of *rotation* of the earth; its intersection with the plane of the horizon is the *meridian line* used in *plane surveying.*

meridian: central (State coordinate system).—The *meridian* used as Axis of *Y* for computing projection tables for a *State coordinate system.*

The central meridian of the system usually passes close to the center of figure of the area or zone for which the tables are computed, but to avoid the use of negative values, is given a large positive abscissa, thus requiring that a large constant quantity be added to all *x coordinates.*

meridian: convergence of meridians.—The angular drawing together of the *geographic meridians* in passing from the *equator* to the poles.

At the *equator,* all *meridians* are mutually parallel; passing from the *equator,* they converge until they meet at the poles, intersecting in *angles* that are equal to their differences of *longitude.* The term convergence of meridians is used to designate also the relative difference of direction of *meridians* at specific points on the *meridians.* Thus, for a *geodetic line,* the *azimuth* at one end differs from the *azimuth* at the other end by 180° plus or minus the amount of the convergence of the meridians at the end points.

meridian: double meridian distance (plane surveying).—The sum of the *meridian distances* of the ends of a survey line.

In practice, assuming a closed *traverse* with the *meridian* of reference passing through the initial station, the double meridian distance (D. M. D.) of the first *course* (line) is equal to the *departure* of that *course;* the double meridian distance of each succeeding *course* (line) is equal to the double meridian distance of the preceding *course,* plus the *departure* of the preceding *course,* plus the *departure* of the *course* itself.

Meridian: Ferro (Hierro).—The conventional Ferro Meridian is 17°37′45″ west of Greenwich, being originally chosen exactly 20° west of the Paris Meridian.

Many European geographers used to reckon longitude from this meridian which was taken as the dividing line between the Eastern and Western Hemispheres.

The conventional Ferro Meridian does not coincide with the neighboring island of the same name.

meridian: geodetic.—A line on a *spheroid* which has the same *geodetic longitude* at every point.

If the *spheroid* is an ellipsoid of revolution, as used for purposes of *triangulation,* a geodetic meridian is an ellipse whose plane contains the minor axis of the *spheroid,* and whose *geodetic azimuth* at every point is 0° (south) or 180° (north).

meridian: geographic.—A general term, applying alike to an *astronomic* or a *geodetic meridian.*

Meridian: Greenwich.—The *astronomic meridian* through the center of the *transit instrument* of the Observatory of Greenwich, England.

meridian: grid.—A line through a point parallel to the central *meridian* or Axis of Y of a system of *plane-rectangular coordinates.*

meridian: guide (United States public-land surveys).*—An auxiliary governing line projected north along an *astronomical meridian,* from points established on the *base line* or a *standard parallel,* usually at intervals of 24 miles east or west of the *principal meridian,* on which *township, section,* and *quarter-section corners* are established.

meridian: magnetic.—The vertical plane in which a freely suspended, symmetrically magnetized needle, influenced by no transient artificial magnetic disturbance, will come to rest. Also, a curve on the earth's surface tangent to such a plane at each place it touches.

meridian: prime.—An initial or zero *meridian* from which other *meridians* are reckoned.

At an International Meridian Conference held in Washington, D. C., in 1884, the adoption of the *Greenwich Meridian* as the prime meridian for the earth was approved by the representatives of 22 governments, there being one objector, while two representatives abstained from voting. See also, *meridian: Washington Meridian.*

meridian: principal (United States public-land surveys).*—A line extending north and south along the *astronomical meridian* passing through the *initial point,* along which *township, section,* and *quarter-section corners* are established.

The principal meridian is the line from which is initiated the *survey* of the *township* boundaries along the *parallels.* Auxiliary meridional governing lines, known as *guide meridians,* are established along the *astronomical meridian* usually at intervals of 24 *miles* east or west of the principal meridian. In some of the very early surveys the principal meridian is referred to as the "basis meridian."

meridian: terrestrial.—An *astronomic meridian.*

For particular use, the term *astronomic meridian* is preferred over terrestrial meridian. For general use, the preferred term is *geographic meridian,* which applies alike to *astronomic* and *geodetic meridians.*

Meridian: Washington.—The *astronomic meridian* through the center of the dome of the old Naval Observatory in Washington, D. C.

The Washington Meridian was used in defining the meridional boundaries of several western States. An Act of Congress, September 28, 1850, provided "That hereafter the meridian of the observatory at Washington shall be adopted and used as the American meridian for astronomic purposes and . . . Greenwich for nautical purposes." This Act was repealed August 22, 1912. See *meridian: Greenwich Meridian.*

meridian distance (astronomy).—The *hour angle* of a celestial body when close to but not exactly on the *astronomic meridian.*

This term appears to be limited to computation forms where it is used to designate the *hour angle* of a star observed slightly off the *meridian* in making *latitude* observations by the *zenith telescope method.*

meridian distance (plane surveying).—The perpendicular distance in a horizontal plane of a point from a *meridian* of reference.

The difference of the meridian distances of the ends of a line is called the *departure* of the line.

meridian line (plane surveying).—The line of intersection of the plane of the *celestial meridian* and the plane of the *horizon.*

It is a horizontal *direction* used in surveying; its *astronomical azimuth* is 0° or 180°.

meridian telescope.—A portable instrument so designed that it can be used as an *astronomical transit,* or quickly converted for use as a *zenith telescope.*

The meridian telescope has a base which is divided horizontally into two parts; the upper part rotates upon the lower part about a short vertical axis. The upper part carries two folding uprights (standards) with wyes which support the horizontal axis of the *telescope.* The *telescope* is equipped with a *vertical circle* to which is attached a sensitive *spirit level.* The *telescope* has a fixed *reticle* for use in making *time* observations, and an *ocular micrometer* for *latitude* work. When used as an *astronomical transit,* the two parts of the base are clamped together. It is converted for use as a *zenith telescope* by removing the clamps, and permitting the upper part to rotate through 180°, stops being placed to bring the *telescope* to rest in the plane of the *meridian.* The meridian telescope is also known as the Davidson meridian instrument, after George Davidson of the U. S. Coast Survey, who designed it in 1858.

meridional orthographic map projection.—See under *map projection: orthographic.*

meridional parts: table of.—A table listing lengths of the *meridian* from the *equator* to the various *parallels* of *latitude* increased in the proportion required to show lengths along the *parallels* equal to the corresponding length along the *equator.*

On a sphere, at the *equator,* the length of a minute of *longitude* is equal to the length of a minute of *latitude,* but on receding from the *equator* and approaching the poles, the minutes of *latitude* remain always the same, while the length of a minute of *longitude* steadily decreases.

Because the earth is not a sphere, the above conditions do not exactly fit it. However, in the *Mercator map projection,* the minutes of *longitude* are made to appear of the same length for all *latitudes,* and it becomes necessary in order to preserve existing proportions between lengths of the *parallel* and of the *meridian* at various *latitudes* to increase the lengths along the *meridian,* such increase being greater and greater, the higher the *latitude.* The length of the *meridian,* thus increased, constitutes the number of the meridional part corresponding to that *latitude.*

Such a table, found in books on navigation, affords facilities for constructing a *Mercator map projection,* and for solving problems in Mercator sailing. A close value of a meridional part on an ellipsoid for a given *geographic latitude* is obtained by computing the meridional part for the corresponding *geocentric latitude.*

metallic thermometer.—A device utilizing the difference of the *coefficients of thermal expansion* of the metals of which it is constructed to determine the temperature of those metals.

The measuring rods used on the *base lines* of the Dunkirk-Barcelona *triangulation* (1791–2) were themselves metallic thermometers. Each rod was composed of a strip of copper lying on a strip of platinum; these were fastened together at one end, leaving their other ends free to move in response to changes in their temperature. A scale on the free end of the copper strip was read by means of a *vernier* on the free end of the platinum strip, thus affording a means of determining the temperature of the bars. This apparatus was constructed by Borda. See *Borda scale.*

meter; metre.—A *unit* of length equivalent in the United States to 39.37 *inches* exactly.

The meter was originally defined (in 1791) as the equivalent of one ten-millionth of the length of the *quadrant* of the *meridian* through Paris (from the *equator* to the North Pole). A *unit* derived by this proportion from several *arcs* of *triangulation* became known as the *French legal meter,* the *standard* constructed to represent it being known as the *Metre des Archives.* Under an International Convention in 1875, the *international meter* was derived from the *Metre des Archives,* and the *International Prototype Meter* adopted as a *standard* by the subscribing governments. Copies of this new *standard,* of the same form and alloy as the original, were furnished the governments which subscribed to the Convention of 1875. The United States received two such copies in 1889, one of which was adopted as the national standard of length, and is known as the *National Prototype Meter.* These two copies are in the custody of the National Bureau of Standards, Washington, D. C. The equivalence, 1 meter equals 39.37 *inches* exactly, was prescribed by Act of Congress in 1866.

At the Seventh General (International) Conference on Weights and Measures (Paris, 1927), the following supplementary value of the meter was temporarily adopted:

1 meter = 1,553,164.13 wave-lengths of the red ray of Cadmium vapor, in dry air, at a temperature 15° Centigrade, at a pressure of 760 millimeters of mercury and under normal conditions of *gravity.* Since this determination was made, the necessity for mak-

ing several slight corrections to the result has been realized and the following relation obtained:

1 meter=1,553,163.7 wave-lengths. The earlier value continues the official value.

meter: Committee Meter.—An iron bar *standard* of one *meter* length, which was brought to America in 1805 by Ferdinand R. Hassler, the first superintendent of the U. S. Coast Survey.

It was one of sixteen such bars which were standardized by the Committee on Weights and Measures in Paris in 1799. It served as the *standard* of length for *geodetic surveys* in this country until 1889 or 1890, when it was replaced by the present *standard*, the *National Prototype Meter*. The Committee Meter was presented by Hassler to the American Philosophical Society in Philadelphia.

meter: French legal.—The *unit* of length defined by the *Metre des Archives*. See *meter; metre.*

meter: international.—The *unit* of length defined by the *International Prototype Meter*. See *meter; metre.*

meter: International Prototype Meter.—A bar *standard* of platinum-iridium which defines the length of the *unit*, the *international meter*.

The International Prototype Meter was produced under the authority and direction of an International Conference held in Paris in 1875, signed by the representatives of 17 governments. It is a line *standard* and was derived from the *Metre des Archives*, an end *standard*. The International Prototype Meter and two other similar bars of the same origin are maintained at the International Bureau of Weights and Measures at Sevres, France, and are used in standardizing the representative copies which were supplied to the governments supporting the Convention of 1875. As a signatory of that convention, the United States received two such representative copies, one of which is known as the *National Prototype Meter*. These copies are in the custody of the National Bureau of Standards, Washington, D. C.

meter: Metre des Archives.—A bar *standard* defining the length of the *French legal meter*.

It is an end *standard*, of platinum, and was used in determining a length for the *International Prototype Meter*. It is now preserved as a museum piece in the International Bureau of Weights and Measures, Sevres, France. See *meter; metre.*

meter: National Prototype Meter.—A *standard* copy of the *International Prototype Meter* which defines the *international meter* as a *unit* of length.

It is a bar of platinum-iridium, of the same form and alloy as the *International Prototype Meter*, and one of the pair received in 1889 from the International Bureau of Weights and Measures, Sevres, France. These bars are in the custody of the National Bureau of Standards, Washington, D. C. They are line *standards*.

method of repetitions, determination of astronomic azimuth.—See under *azimuth*.

micrometer: correction for run of.—A *correction* applied to an observed reading of a graduated circle made with a *micrometer microscope* to compensate for *run of micrometer*.

Specific application of this correction is not required in present-day observations with a *direction instrument*, being neutralized by instrumental adjustment and method of observing.

micrometer: eyepiece.—See under *micrometer: ocular*.

micrometer: filar.—A device attached to a *telescope* or microscope, consisting of a wire thread (filament) connected with a screw in such manner that as the screw is turned, the wire moves through a continuous succession of parallel positions, all in the focal plane of the instrument.

The screw has a fine thread, accurately cut, and calibrated in terms of angular measure (seconds of *arc*): one turn of the screw moves the wire a distance that may be expressed as a certain number of seconds, corresponding to the *angle* at the instrument between two objects which would be bisected by the wire in its two positions. Any small *angle* may be measured by noting the number of turns and fractions of a turn of the screw which are made in moving the wire from one bisection to another, and multiplying this by the value of one turn. See *micrometer: ocular; micrometer microscope.*

micrometer: impersonal.—See under *micrometer: transit micrometer*.

micrometer: ocular.—A *filar micrometer* so placed that its wire moves in the principal focal plane of a *telescope*. Also termed an eyepiece micrometer.

The ocular micrometer is used in *surveying* and astronomic work for making accurate and precise measures of small *angles* between lines to objects viewed with the *telescope*. It is mounted in a frame which is perpendicular to the longitudinal axis of the *telescope*, and can be rotated to measure an *angle* in any plane containing that axis. It may be adjusted to measure *angles* in a plane which contains the longitudinal and horizontal axes of the *telescope*, as in observing *time* using the *transit micrometer* (which is an ocular micrometer); or it may be adjusted to measure *angles* in a plane containing the longitudinal axis but perpendicular to the *horizontal axis* of the *telescope*, as in observing *latitude* with the *zenith telescope*.

micrometer: run of.—The difference in seconds of *arc* between the intended value of one complete turn of a micrometer screw used in reading a graduated circle and its actual value as determined by measuring with the micrometer the space between two adjacent *graduation* marks on the circle.

This quantity has sometimes been called the error of run, but the above designation is more generally used and is preferred. It is an *error*, but is kept quite small by instrumental adjustment, and its effect on observed values is neutralized by methods of observing. See *micrometer: correction for run (of micrometer)*.

micrometer: transit.—A form of registering micrometer with its movable wire placed in the *focal plane* of an *astronomic transit* and at right *angles* to the direction of motion of the image of a star which is observed at or near *culmination*. Certain contact points on the micrometer head (wheel) serve to make an electric circuit as they pass a fixed contact spring, thus producing a record on the *chronograph* sheet at each separate instant when the micrometer wire reaches a position corresponding to a contact.

The transit micrometer is also called an impersonal micrometer, because it almost completely eliminates the effect of *personal equation* from time observations made with it.

micrometer method, determination of astronomic azimuth.—See under *azimuth*.

micrometer microscope.—A *filar micrometer* so placed that its wire moves in the focal plane of a microscope.

Using a micrometer microscope, readings of a graduated circle are made with a high degree of *accuracy* and *precision*. The micrometer is so adjusted that an even number of turns will carry the wire exactly the distance between adjacent *graduation* marks on the circle. Any intermediate point on the circle may then be read with the micrometer by interpolation. If the adjustment is imperfect, the amount by which an even number of turns of the screw fails to carry the wire exactly the distance between *graduation* marks is treated as a *systematic error* and is termed by preference the *run of micrometer*. The designation error of run of micrometer is also applied to it.

middle ordinate.—The distance from the middle point of a chord to the middle point of the corresponding circular *arc*.

middle point (M. P.).—That point on a circular curve which is at the same distance from both ends of the curve.

mil.—See under *angle (general)*, (e).

mile.—A unit of distance. See under *mile: nautical mile; statute mile.*

The term mile is derived from the Latin "mille," meaning a thousand, and applied to the double *pace* of 5 *feet*. The mile of the Romans was 5,000 *feet*, a value that suffered many changes as the mile came into use among the western nations.

mile: geographical.—See under *mile: nautical mile.*

mile: nautical.—A length of *mile* used in ocean navigation.

The United States nautical mile is defined as equal to one-sixtieth of a degree of a *great circle* on a sphere whose surface is equal to the surface of the earth. Its value, calculated for the *Clarke spheroid of 1866*, is 1,853.248 *meters* (6,080.20 feet). The international nautical mile is 1,852 *meters* (6,076.10 feet). The United States nautical mile is also called a sea mile or a geographical mile, and may be taken as equal to the length of a minute of *arc* along the *equator* or a minute of *latitude* on the *map* which is being measured.

mile: sea.—See under *mile: nautical mile.*

mile: statute.—A length of *mile* used in distance measurements on land, and equal to 5,280 feet (1,609.35 *meters*).

military grid.—A quadrillage or system of squares determined by rectangular coordinates on a spherical *map projection*, referred to one origin, and extended over the whole area of the original *map projection*.

A military grid is designed to make data presented on a *map* more readily available for military purposes.

milligal.—See *gal.*

millionth-scale map of the World.—An informal designation for the *International Map of the World* which is being constructed on a scale of 1 : 1,000,000.

minus sight.—See under *foresight (leveling)*.

missing triangle (pendulum).—A triangle which represents the failure of the two sides of a *knife edge* to reach a perfect intersection in a geometric line.

In the most nearly perfect *knife edge* that can be made, the two planes of the *knife edge* will not quite meet. The base of the missing triangle which is thereby formed is found by optical means to be less than one micron.

modified polyconic map projection.—See under *map projection.*

Molitor leveling rod.—See under *leveling rod: Molitor precise leveling rod.*

Mollweide homalographic map projection.—See under *map projection.*

month.—A measure of *time* based on the motion of the moon in its orbit.

There are various kinds of month defined by the references which determine them. See *month: anomalistic month; calendar month; nodical month; sidereal month; synodical month.*

month: anomalistic.—The interval of *time* between two successive passages of the moon in her orbit through *perigee*.

The length of the anomalistic month is 27.55455 *mean solar days.*

month: calendar.—A division of the *year* as determined by a calendar, approximately one-twelfth of a *year* in length.

While arbitrary in character, the calendar month is based roughly on the *synodical month*. The calendar month ranges in length from 28 to 31 *mean solar days.*

month: lunar.—A *synodical month.*

month: nodical.—The interval of *time* between two successive passages of the moon through the same node of her orbit.

The length of the nodical month averages 27.21222 *mean solar days.*

month: sidereal.—The interval of *time* it takes the moon to make its *revolution* from a given star back to the same star again.

The sidereal month may be measured by the interval of *time* it takes the moon to revolve from a given *celestial longitude* back to the same longitude again, reckoned from a fixed *equinox*. The length of the sidereal month averages 27.321661 *mean solar days.* Because of perturbations, the actual length varies some 7 hours. The difference between the lengths of the sidereal and *tropical months* is due to the *precession of the equinoxes*. The above definition is not precise: the moon will not return to the same *declination* at the end of a sidereal month.

month: synodical (ordinary).—The interval of *time* between two successive conjunctions (new moons) or oppositions (full moons) of the moon. Also called a lunation.

The length of the synodical month is 29.530588 *mean solar days.* It is the *month* intended when a *lunar month* is specified. Synodical is preferred over synodic, which is sometimes used.

month: tropical.—The interval of *time* it takes the moon to make its *revolution* from a given *equinox* back to the same *equinox* again.

The tropical month may be measured by the interval of *time* it takes the moon to revolve from a given *celestial longitude* back to the same *longitude* again, reckoned from an *equinox* affected by precession. The length of the tropical month averages 27.321582 *mean solar days.* Because of perturbations, the actual length varies some 7 hours. The difference between the lengths of the *sidereal* and tropical months is due to the *precession of the equinoxes.*

monument.—Any material object or collection of objects which indicates the position on the ground of a survey station or land corner.

The term monument may include the mark at the center or station and all marks which are directly related to it by surveying processes and are aids in its recovery and identification. In *land surveying* the term may include also objects such as roads, ditches, fences, etc., which form a bound for the land. It is well therefore in treating of survey stations to use the designations station mark or center mark, *reference mark*, and *witness mark* for the separate marks; and in *land surveying*, unless monument is used in a general sense, to use the particular terms, *corner*, or corner mark, *reference mark*, and *witness mark*. Note that a *witness mark* has more authority in *land surveying* than in *control surveying*.

monument (United States public-land surveys).*—A physical structure which marks the location of a *corner* or other survey point.

Monument and *corner* are not synonomous, though the two terms are often used largely in the same sense.

mountain barometer.—See under *barometer*.

multiple level line.—See under *level line*.

N

nadir.—The point where the direction of the plumb-line extended below the *horizon* meets the *celestial sphere*.

The nadir is directly opposite the *zenith*.

national control survey nets.—See under *control*.

national mapping plan.—See under *mapping plan*.

National Prototype Meter.—See under *meter*.

nautical chart.—See under *chart*.

nautical mile.—See under *mile*.

navigable waters.—The waters which are used or are susceptible of being used, in their ordinary condition or after reasonable improvements have been made, as highways for commerce in the customary means of travel on water.

net (leveling).—A series of *lines of levels* which have been interconnected in such a manner that closed loops or *circuits* have been formed.

network (leveling).—See *net (leveling)*.

New England datum.—See under *datum*.

Newtonian constant of gravitation.—See under *gravitation: constant of gravitation*.

New York leveling rod.—See under *leveling rod*.

nodal point of a lens, first and second.—The intersections of the *principal axis* with the (produced) incident and emergent parts, respectively, of any ray having those parts parallel to each other.

nodical month.—See under *month*.

nomogram.—A chart or drawing showing, to scale, the relationship between known and dependent variables, in such manner that a value of a dependent variable corresponding to a stated value of the known variable can be scaled from the chart.

Nomograms are used in the graphical solution of formulas where the *precision* of the result does not require numerical computation.

nomograph.—A *nomogram*.

Although the term nomograph is given the preference in Webster's International Dictionary, *nomogram* is preferred in the several texts consulted.

normal.—In general, a straight line perpendicular to a surface or to another line. Also, a condition of being perpendicular to a surface or line. In *geodesy*, a straight line perpendicular to the surface of the *spheroid*.

While the term normal is correctly used to designate also a line perpendicular to the surface of the *geoid*, the term *vertical* is preferred for such a line. The term normal, in general, applies to a line of unspecified length, but some writers use it to designate the length of line between the surface of the *spheroid* and the minor axis, giving it the designation "N". To this particular line the French apply the term "great normal". This length is the radius of curvature of a *prime vertical* section of the spheroid.

normal equation.—See under *equation*.

normal section azimuth.—See under *azimuth: normal section*.

normal section line.—A line on the surface of the *spheroid*, connecting two points on that surface, and traced by a plane containing the *normal* at one point and passing through the other point.

There can be two such lines connecting any two points (as A and B) on the *spheroid:* one defined by the plane containing the *normal* at A and passing through B; the other containing the *normal* at B and passing through A. Where the two points are on the same parallel of *latitude* or on the same meridian of *longitude*, the two lines will be coincident.

North American datum.—See under *datum*.

North American datum of 1927.—See under *datum*.

north star.—See under *Polaris*.

northing.—See under *latitude: difference of latitude (plane surveying)*.

nutation.—A periodic motion of the celestial poles.

O

obliquity of the ecliptic.—See under *ecliptic*.

obliterated corner (United States public-land surveys).—See under *corner*.

observation: direct.—A measure of the quantity whose value is desired.

Example: a single measure of a *horizontal angle*.

observation: indirect.—A measure of a quantity which is a function of the quantity or quantities whose value is desired.

Example: an observed difference of *elevation* with a *spirit level*, used to obtain the *elevation* of a *bench mark*.

observation equation.—See under *equation*.

observed angle.—See under *angle*.

observed value.—See under *value*.

occultation.—The disappearance of a body behind another body of larger apparent size.

When the moon passes between the observer and a star, the star is said to be occulted. The three associated terms, occultation, *eclipse*, and *transit*, are exemplified by the motions of the satellites of Jupiter. An *eclipse* occurs when a satellite passes into the shadow cast by the planet; an occultation occurs when a satellite passes directly behind the planet, so that it could not be seen even if it were illuminated; and a transit occurs when a satellite passes between the observer and the planet, showing against the disk of the planet. The occultation of stars by the moon furnishes a method of determining *latitude* and *longitude* used in early *surveys,* particularly those of an exploratory character.

odometer.—A *revolution* counter which is attached to the wheel of a vehicle and registers the number of turns made by the wheel in traveling over the ground.

An odometer is used in obtaining an *approximate* value of the distance traveled, the number of *revolutions* being multiplied by the circumference of the wheel. See *passometer.*

offset.—A short line perpendicular to a surveyed line, measured to a line or point for which data are desired, thus locating the second line or point with reference to the first or surveyed line. An offset is also a jog in a *survey* or other line, the line having approximately the same direction both before and after passing the jog.

Offsets are measured from a surveyed line or lines to the edges of an irregular-shaped body of water, or to any irregular line which it is desired to locate.

offset (United States public-land surveys).—A perpendicular distance measured from a *great circle line* to a *parallel* of *latitude,* to locate a *section corner* on that *parallel.* See *secant method (United States public-land surveys); tangent method (United States public-land surveys).*

offset line.—A supplementary line close to and roughly parallel with a main line, to which it is referred by measured *offsets.*

Where the line for which data are desired is in such position that it is difficult to measure over it, the required data are obtained by running an offset line in a convenient location and measuring *offsets* from it to salient points on the other line.

Old Hawaiian datum.—See under *datum.*

optical axis (lens).—See under *principal axis.*

optical base-line measuring apparatus.—See under *base apparatus.*

optical parallax.—See under *parallax: instrumental parallax.*

optical square.—A small hand instrument used in setting off a right *angle.*

One form of optical square employs two plane mirrors placed at an *angle* of 45° to each other. In use, one object is sighted direct, and another object is so placed that its twice-reflected image appears directly in line with the first object. The lines to the point of observation from the two observed objects will then meet in a right *angle.* In another form of optical square, a single plane mirror is so placed that it makes an *angle* of 45° with a sighting line; one object is sighted direct, and the other so placed that its reflected image is seen also in the sighting line.

optical vernier.—See under *vernier.*

orientation.—The act of establishing correct relationship in direction with reference to the points of the compass; the state of being in correct relationship in direction with reference to the points of the compass.

A *map* is in orientation when the *map* symbols are parallel with their corresponding ground features. A *plane table* is in orientation when lines connecting positions on the *plane table* sheet are parallel with the lines connecting the corresponding ground objects. A surveyor's *transit* is in orientation if the horizontal circle reads 0° when the *line of collimation* is parallel to the direction it had at an earlier (initial) position of the instrument, or to a standard line of reference. If the line of reference is a *meridian,* the circle will show *azimuths* referred to that *meridian.*

A photograph is in orientation when it correctly presents the perspective view of the ground directly in front of the observer; or when images on the photograph appear in the same direction from the point of observation as do the corresponding map symbols.

origin of coordinates.—See under *coordinates.*

orthodrome.—An obsolete term descriptive of a *great circle.*

orthographic map projection.—See under *map projection.*

orthometric correction.—See under *correction.*

orthometric elevation.—See under *elevation.*

orthomorphic map projection.—See under *map projection.*

oscillation (pendulum).—A double motion, one in each direction, of a *pendulum.* An oscillation is composed of two consecutive *vibrations.*

In some texts, a *vibration* is called a simple oscillation, and an oscillation is called a double or complete oscillation.

outcrop.—The exposed portion of a rock stratum or vein at the surface of the earth.

In describing a *survey* station, the exposed portion of a large boulder is sometimes mistaken for an outcrop.

outline map.—See under *map.*

P

pace.—The distance a pedestrian moves in taking one step.

See *stride.*

Panama-Colon datum.—See under *datum.*

parallactic error.—See under *error.*

parallax (general).—1. The difference in the direction of an object as seen by an observer and as seen from some standard point of reference. 2. An apparent displacement of the position of the body with respect to a reference point or system caused by a shift in the point of observation.

Parallax enters into many problems of astronomy, *surveying,* and mapping. It is an inclusive term, and wherever clarity demands, it should be accompanied by a defining adjective. See *annual parallax, diurnal parallax, secular parallax, instrumental parallax,* and proposed new terms, *optical parallax,* and *personal parallax.* Parallax is also a basic term in photogrammetry, being qualified as "linear parallax," "stereoscopic parallax," etc.

parallax: annual.—The difference between the direction from the earth to a star and the direction from the sun to the same star. Also termed heliocentric parallax.

The annual parallax of a given star is equal to the *angle* at the star subtended by the radius of the earth's orbit. See *parsec.* Annual parallax does not enter into any *surveying* problems.

parallax: diurnal.—The difference between the direction from a point on the surface of the earth to a planet, star, or other celestial object, and the direction from the center of the earth to the same object. Also termed geocentric parallax.

Diurnal parallax at a given point on the surface of the earth changes in magnitude as the earth rotates on its axis: it is greatest when the celestial object is in the *horizon* of the given point, when it is equal to the *angle* at the object subtended by the semidiameter of the earth, and is termed horizontal parallax. The *angle* at a celestial object subtended by the equatorial semidiameter of the earth is termed equatorial horizontal parallax, and is used to indicate the distance of the object from the earth.

Of less importance to the surveyor is *annual* or *heliocentric parallax*, the difference of directions to a star from the earth and from the sun, and of no importance whatever is secular parallax, due to the slow progressive motion of the solar system through space.

parallax: equatorial horizontal.—See under *parallax: diurnal parallax.*

parallax: geocentric.—See under *parallax: diurnal parallax.*

parallax: heliocentric.—See under *parallax: annual parallax.*

parallax: horizontal.—See under *parallax: diurnal parallax.*

parallax: instrumental.—A change in the apparent position of an object with respect to the reference mark(s) of an instrument which is due to imperfect adjustment of the instrument or to a change in the position of the observer.

When a *telescope* is poorly focused, so that the image of the object does not lie in the plane of the *reticle* (cross hairs), a movement of the eye transverse to the *line of collimation* will cause an apparent movement of the image of the object with respect to the cross hairs. This is a usual form of instrumental parallax, and for it the term optical parallax is proposed. *Parallax* may also result from the position in which an observer stands with respect to the *fiducial marks* on an instrument, as when reading a *vernier* or marking a tape end; for this type of *parallax* the term personal parallax is proposed.

parallax: optical.—See under *parallax: instrumental parallax.*

parallax: personal.—See under *parallax: instrumental parallax.*

parallax: secular.—See under *parallax: diurnal parallax.*

parallax: solar.—The *equatorial horizontal parallax* of the sun.

Solar parallax is the basis for the determination of the *astronomical unit,* and is used in some astronomical calculations as a measure of distance in place of that unit.

parallel: astronomic.—A line on the surface of the earth which has the same *astronomic latitude* at every point.

Because the *deflection of the vertical* is not the same at all points on the earth, an astronomic parallel is an irregular line, not lying in a single plane. The astronomic parallel of 0° *latitude* is called the *astronomic equator;* also called the *terrestrial equator.*

parallel: auxiliary standard (United States public-land surveys).*—A new *standard parallel* or *correction line* established, when required, for control purposes where original *standard parallels* or *correction lines* were placed at intervals of 30 or 36 miles.

Auxiliary standard parallels are used in the extension of old *surveys* and for the control of new *surveys.* Such a line may be given a local name, as "Cedar Creek Correction Line," or "Fifth Auxiliary Standard Parallel North."

parallel: geodetic.—A line on the *spheroid* which has the same *geodetic latitude* at every point.

A geodetic parallel, other than the *equator,* is not a *geodetic* (*geodesic*) *line.* In form, it is a small circle whose plane is parallel with the plane of the *geodetic equator.*

parallel: geographic.—A line on the earth having the same *latitude* at every point.

The term is applicable alike to an *astronomic parallel* or to a *geodetic parallel.*

parallel: standard (cartography).—A *parallel* of *latitude* which is used as a control line in the computation of a *map projection.*

In illustrations of *map projections* of the conic type, a standard parallel usually represents a line of tangency or of intersection of a cone with the surface of the *spheroid.* Such illustrations are not exact.

parallel: standard (United States public-land surveys).*—An auxiliary governing line established along the *astronomic parallel,* initiated at a selected *township corner* on a *principal meridian,* usually at intervals of 24 miles from the *base line,* on which *standard township, section,* and *quarter-section corners* are established; also known as a "correction line."

Standard parallels, or "correction lines" are established for the purpose of limiting the convergence of *range lines* from the south.

parallel of altitude.—See under *almucantar.*

parallel of declination.—See under *declination.*

parametric latitude.—See under *latitude.*

Parkhurst theodolite.—See under *theodolite.*

parsec.—The distance at which the *annual parallax* is equal to one second of *arc* (1").

partial (leveling).—See *divergence* (*leveling*).

passometer.—A pocket-size instrument which registers the number of steps taken by the pedestrian carrying it.

The passometer is housed in a case resembling a watch case and is carried in an upright position attached to the body or to a leg. The distance walked is obtained by multiplying the number of steps taken by the length of a *pace,* or of a *stride,* if double steps are registered. See also *pedometer.*

pedometer.—A pocket-size instrument which registers the distance in linear units traversed by the pedestrian carrying it.

The term pedometer was formerly applied also to an instrument which registered the number of steps taken, but for which the term *passometer* is now used. The pedometer, like the *passometer,* is housed in a case resembling a watch case, and is carried in an upright position attached to the body or to a leg. It registers the linear distance traveled in miles or other units, the number of steps taken being mechanically transformed into linear units. This transformation depends upon the length of a *pace,* which may be different for different persons. The pedometer can be adjusted to the length of the *pace* of the person carrying it.

peg adjustment.—A method of adjusting a *leveling instrument* of the *dumpy level* type, to make the *line of collimation* parallel with the *axis of the spirit level,* and employing two stable marks (pegs) the length of one instrument sight apart.

The peg adjustment can be used with a *wye level,* but such an instrument is more readily adjusted by reversing the *telescope* in its wyes. A form of peg adjustment is used in determining the *collimation error* of *first-order leveling instruments* of the *dumpy level* type.

Pemberton leveling rod.—See under *leveling rod: Pemberton rod.*

pendulum.—In general, a body so suspended as to swing freely to and fro under the influence of *gravity* and momentum. See *pendulum: simple pendulum; compound pendulum.*

pendulum: bronze.—A quarter-meter *pendulum* used by the U. S. Coast and Geodetic Survey, and made of aluminum bronze consisting of one part of aluminum and nine parts of copper.

Beginning in 1920, bronze pendulums were replaced by *invar pendulums* in the *gravity* work of the U. S. Coast and Geodetic Survey.

pendulum: compound.—Any actual *pendulum.*

A compound pendulum may be considered as composed of an indefinitely large number of material particles, at different distances from the *center of suspension,* each constituting a *simple pendulum.* The period of *vibration* (*oscillation*) of the compound pendulum may be taken as a resultant of the periods of the *simple pendulums* of which it is composed.

pendulum: dummy.—A *pendulum* of similar construction to the *working pendulums* except that it is equipped with a thermometer and is fastened rigidly in the *receiver* so that it cannot swing during observations.

The dummy pendulum is subject to the same temperature conditions as the *working pendulums,* and is used in determining their temperature when in use.

pendulum: free-swinging.—A *pendulum* moving wholly under the influence of *gravity* and an initial momentum imparted to it by mechanical or other means.

In *gravity* work, the initial momentum may be imparted by drawing the *pendulum* slightly out of plumb and then releasing it.

pendulum: idle.—A *working pendulum* placed in the receiver in advance of its being used, so that it may assume the same temperature as the *dummy pendulum.*

pendulum: invar.—A quarter-meter *pendulum* used by the U. S. Coast and Geodetic Survey, and made of an alloy consisting of approximately one part of nickel and two parts of iron.

Beginning in 1920, invar pendulums have replaced *bronze pendulums* in the *gravity* work of the U. S. Coast and Geodetic Survey. The invar pendulum is subject to magnetization, and has a *coefficient of thermal expansion* about one-fifteenth that of the *bronze pendulum* which it replaced. In general, the two *pendulums* are quite similar, the weight of the invar pendulum being somewhat greater and its bob a little thicker at the middle.

pendulum: invariable.—A *pendulum* so designed and equipped with means of support that it can be used in only one position.

With an invariable pendulum, the *centers of suspension* and *of oscillation* are not interchangeable in use. *Pendulums* of this type have been constructed by Kater, Peirce, and Mendenhall. They may be used only for relative measurements of the *intensity of gravity.*

pendulum: Mendenhall.—An *invariable pendulum,* one-quarter meter in length, with a *vibration* period of one-half second, composed of a lenticular-shaped bob on a thin stem, swung in an airtight case from which the air has been largely exhausted.

This *pendulum* was designed in 1890 by Superintendent Mendenhall and assistants of the U. S. Coast and Geodetic Survey. It is the form of *pendulum* used since then by that Bureau in determinations of the *intensity of gravity,* but has undergone various improvements in mounting, methods of observation, etc.

pendulum: reversible.—A *pendulum* so designed and equipped with means of support that it may be used with either end up or down.

With a reversible pendulum, the *centers of suspension* and *of oscillation* are interchangeable in fact. This type of *pendulum* is exemplified by *pendulums* constructed by Kater, by Peirce, and by Repsold. Reversible pendulums may be used for absolute measurements of the *intensity of gravity* at base stations. See *pendulum: invariable.*

pendulum: simple.—A theoretical concept: a heavy particle suspended from a fixed point by a fine thread which is inextensible and without weight.

A simple pendulum cannot be realized in actual work. A simple pendulum is, however, the basis of reductions of observations made with an actual *pendulum.* Those observations have *corrections* applied to them to obtain results which would have been produced by an equivalent simple pendulum.

pendulum: temperature correction.—The quantity that is applied to the period of *vibration* of a *pendulum* to allow for the difference in the length of the *pendulum* at the temperature of observation and its length at some other temperature which has been adopted for purposes of *standardization* or for combining or comparing corresponding values.

In the work of the U. S. Coast and Geodetic Survey, the temperature adopted for these purposes is 15° centigrade.

pendulum: working.—A *pendulum* which is used (swung) in a determination of the *intensity of gravity.*

perigee.—The point in the orbit of the moon nearest to the earth.

perihelion.—The point in the orbit of a planet or comet closest to the sun.

Perihelion of the earth's orbit provides the index for the *anomalistic year.*

permanent bench mark.—See under *bench mark.*

perpendicular equation (traverse).—See under *equation.*

personal equation.—The *time* interval between the sensory perception of a phenomenon and the motor reaction thereto.

Personal equation may be either positive or negative, as an observer may anticipate the occurrence of an event, or wait until he actually sees it occur before making a record.

This is a *systematic error,* treated as of the constant type. It is a *personal error,* for which the term personal equation is reserved. It is of especial significance in observations of *time,* made to determine *clock correction.* For example, it is the elapsed *time* between the seeing of the event, star bisected by wire, and the recording of that event by mechanical (*chronograph*) means or by other method (eye-and-ear). Because of its significance in such work, special means have been developed for its control. See *micrometer: transit.*

personal error.—See under *error.*

personal parallax.—See under *parallax: instrumental.*

perspective map projection.—See under *map projection.*

perspective map projection upon a tangent cylinder.—See under *map projection.*

phase.—The visible aspect of an object.

In astronomy, phase is a stage in a cycle of recurring aspects, caused by a systematic variation of the illumination of an object. The moon passes through its phases, new moon to full moon and back to new moon, as its position relative to the sun and earth changes. In *surveying,* phase is applied to a signal which presents areas of varying brightness to the observer: a round pole, illuminated from the side; a square pole, of which the observer sees two sides, one more strongly illuminated than the other. The *error* in pointing due to phase is of the same character and requires the same treatment as an *error* due to observing an *eccentric object*. Phase may be closely associated with *asymmetry of object* (target), but the two terms are not identical.

Philadelphia leveling rod.—See under *leveling rod: Philadelphia rod.*

physiographic feature.*—A prominent or conspicuous *physiographic form* or salient part thereof.

physiographic form.*—A *land form* considered with regard to origin, cause, or history.

physiography.*—The classification of the genesis of *land forms.*

pivot inequality.—Any difference in the diameters or any irregularities in the form of the pivots of the *horizontal axis* of a surveying or astronomical instrument (*theodolite, transit,* etc.).

Though formerly taken into account in the computation of astronomical observations made in connection with *geodetic surveys,* corrections for pivot inequality have been rendered unnecessary by the production of instruments having pivots which are *accurate* and *precise* in size and form.

plane (pendulum).—A suspension bearing used in the support of a *pendulum.*

In the *Mendenhall pendulum,* an agate plane is mounted in the head of the *pendulum;* this bears on an agate *knife edge* which is mounted in the *receiver.* Since 1940, the positions of plane and *knife edge* in some *pendulums* have been reversed.

plane coordinates: State coordinate system.—See under *State coordinate systems.*

plane elliptic arc.—Any part of the line formed by the intersection of a plane and an *ellipsoid.*

plane rectangular coordinates.—See under *coordinates.*

plane survey.—See under *surveying: plane.*

plane surveying.—See under *surveying.*

plane table (surveying).—A device for plotting the lines of a *survey* directly from the observations.

A plane table consists essentially of a drawing board on a tripod, with a ruler, the ruler being pointed at the object observed by means of a telescope or other sighting device.

planimeter.—A mechanical integrator for measuring the area of a plane surface.

Using a planimeter, the *map* area within a given perimeter can be measured; by application of a factor derived from the *map scale,* the *map* area can be transformed into the corresponding area on the earth. There are several forms of planimeters, depending on the same mathematical principles, but differing in their mechanical design and operation. The one most generally used in map work is the polar planimeter; other well-known forms are the rolling planimeter and the suspended planimeter.

planimetric map.—See under *map.*

planimetry.—The mensuration of plane surfaces.

In mapping, planimetry is the determination of horizontal distances, *angles,* and areas, by measurements on a *map.*

planisphere.—A representation on a plane of the circles (*parallels, meridians,* etc.) of a *sphere.*

A particular form of a planisphere is a *polar map projection* of the *celestial sphere,* with movable parts which can be adjusted to show the visible aspect of the heavens at any given time, thereby aiding in the selection and identification of stars for various purposes. The planisphere is the basis of the *planispheric astrolabe.*

planispheric astrolabe.—See under *astrolabe.*

plat (general).*—A diagram drawn to *scale* showing all essential data pertaining to the boundaries and subdivisions of a tract of land, as determined by *survey* or protraction.

A plat should show all data required for a complete and accurate description of the land which it delineates, including the *bearings* (or *azimuths*) and lengths of the boundaries of each subdivision. A plat may constitute a legal description of the land and be used in lieu of a written description.

plat (United States public-land surveys).*—The term *plat,* as employed technically by the U. S. General Land Office, refers to the drawing which represents the particular area included in a survey, such as a *township,* private land claim, or mineral claim, and the lines surveyed, established, retraced, or resurveyed, showing the direction and length of each such line; the relation to the adjoining official surveys; the boundaries, descriptions, and area of each parcel of land subdivided; and, as nearly as may be practicable, a representation of the *relief,* and improvements within the limits of the *survey.*

A public-land survey does not obtain complete official or legal status until the field notes and the *plat* have been approved by the proper supervising officer, and accepted by the Commissioner of the General Land Office.

plot.—To place *survey* data upon a *map* or *plat.*

In past use, no clearly defined difference existed between *plat* and plot. It is suggested that a difference be established by limiting *plat* to the graphical representation of a *survey,* and plot to the cartographic operations involved in the construction of a *map* or *plat.*

plus distance.—The distance along a *survey* line from a *survey station* or the last even-numbered *survey* point to a supplementary point.

A stake is set at 515.56 feet from the initial point of a *survey* line and is not the terminal of that line: the even 500-foot point is station No. 5; the stake is a *plus station* (No. 5+15.56), and 15.56 feet is a plus distance.

plus sight.—See under *backsight (leveling).*

plus station.—An intermediate point on a *survey* line, not at an even tape length distance from the initial point. See *plus distance.*

point.—A position on a reference system determined by a *survey.* A *fix.*

point: turning (leveling).—A point on which a *foresight* is taken from one *instrument station* in a *line of levels* and on which a *backsight* is taken from the next instrument station in the *running* and which is established simply for the purpose of allowing the *leveling instrument* to be moved forward along the line of levels without a break in the series of measured differences of elevation.

A turning point may be a steel pin driven in the ground, the head of a hold-down spike on a railroad track, a nail driven in a tie of a railroad track, a ball bearing set in a small dent in a concrete pavement, etc.

point of compound curvature.—See under *curve.*

point of curvature.—See under *curve.*

point of intersection.—See under *curve.*

point of tangency.—See under *curve.*

pointers: the pointers.—The second-magnitude stars, Alpha and Beta, in the constellation Ursa Major (Big Dipper), the line through which points to *Polaris.*

The pointers facilitate the finding and identification of *Polaris.* They are in the outer side of the "bowl" of the Big Dipper, away from the handle.

polar coordinates.—See under *coordinates*.

polar distance.—The complement of the *declination* (*co-declination*) or 90° minus the *declination*.

Polar distance forms one side, celestial body to pole, of the *astronomical triangle*. It is opposite the *zenith*.

polar orthographic map projection.—See under *map projection: modified polyconic*.

Polaris.—The second-magnitude star, Alpha, in the constellation Ursa Minor (Little Dipper).

Also known as the polestar, or north star, because of its proximity to the north pole of the *celestial sphere*, Polaris is well situated for determinations of *astronomical azimuth*, and for the determination of the direction of the *celestial meridian*. It is at the extreme outer end of the handle of the "Little Dipper." See *pointers: the pointers*.

polestar.—See under *Polaris*.

polyconic map projection.—See under *map projection*.

polyconic map projection, modified.—See under *map projection*.

polyconic map projection, transverse.—See under *map projection: transverse polyconic*.

Port Clarence datum.—See under *datum*.

position.—1. Data which define the location of a point with respect to a reference system. The place occupied by a point on the surface of the earth. The *coordinates* which define the location of a point on the *geoid* or *spheroid*.

2. A prescribed setting (reading) of the horizontal circle of a *direction theodolite* to be used for the observation on the initial station of a series of stations which are to be observed on.

The term as defined under 2 (above) indicates a definite position of the horizontal circle. For example, in *first-order triangulation*, using a two-micrometer *direction theodolite*, in Position No. 1, the circle is set to read 0° 00′ 40″ when the initial station is observed; in Position No. 2, the circle is set to read 11°01′50″ when the initial station is observed; etc.

position: adjusted.—An *adjusted value* of the coordinate position of a point on the earth.

In the adjustment of a horizontal *control survey*, *discrepancies* arising from *errors* in the observational data are removed, and position data of the survey stations are correlated and coordinated on an adopted reference system (*geodetic datum* or *plane-coordinate system*). The positions which are obtained by the adjustment are called adjusted positions, and when used as control for other work are referred to as fixed positions. In the adjustment of a vertical control survey, the values obtained are adjusted elevations, called fixed elevations when used to control other work.

position: field.—A *position* computed while field work is in progress to determine the acceptability of the observations or to provide a *preliminary position* for other purposes.

position: fixed.—See under *position: adjusted position*.

position: geodetic.—A position of a point on the surface of the earth expressed in terms of *geodetic latitude* and *geodetic longitude*.

A geodetic position implies an adopted *geodetic datum*. In a complete record of a geodetic position, the *datum* must be stated.

position: geographic.—The position of a point on the surface of the earth expressed in terms of *latitude* and *longitude*, either *geodetic* or *astronomic*.

The U. S. Coast and Geodetic Survey uses the term geographic positions for positions on a *geodetic datum*.

position: preliminary.—See under *preliminary*.

position: relative.—The location of a point with respect to other points.

The relative position of two points whose positions are given on the same coordinate system is the difference of their *coordinates*, which may also be expressed by a *direction* and distance.

position line.—See under *line of position*.

postal map.—See under *map*.

post route map.—See under *map*.

Pratt theory of isostasy.—See under *isostasy*.

precession.—See under *precession of the equinoxes*.

precession of the equinoxes.—A slow western movement of the *equinoxes*.

Precession of the equinoxes amounts to about 50″ per year and causes the difference in length between the *sidereal* and *tropical years*.

precise level.—See under *leveling instrument*.

precise leveling.—See under *leveling: first-order*.

precise triangulation.—See under *triangulation*.

precision.*—Degree of refinement in the performance of an operation or in the statement of a result.

Precision relates to the quality of execution, and is distinguished from *accuracy* which relates to the quality of the result. The term precision not only applies to the fidelity with which required operations are performed, but by custom has been applied to methods and instruments employed in obtaining results of a high order of *accuracy*. Precision is exemplified by the number of decimal places to which a computation is carried and a result stated. In a general way, the *accuracy* of a result should determine the precision of its expression. Precision is of no significance unless *accuracy* is also obtained.

preliminary.—Not of the desired *accuracy* and *precision*, and adopted for temporary use with the proviso of later being superseded.

In the *adjustment* of *triangulation*, the term preliminary is applied to triangles and *geographic positions* derived from selected observations for use in forming *latitude* and *longitude condition equations*.

preliminary elevation.—See under *elevation*.

preliminary position.—See under *preliminary*.

preliminary survey.—See under *survey*.

preliminary triangle.—See under *preliminary*.

Pribilof Islands datums.—See under *datum: St. George Island datum; St. Paul Island datum*.

primary triangulation.—See under *triangulation*.

prime meridian.—See under *meridian*.

prime vertical.—A *vertical circle* perpendicular to the plane of the *celestial meridian*.

The plane of the prime vertical cuts the *horizon* in the east and west points.

principal axis (of a lens).—The line *normal* to both surfaces of a lens.

In a well-centered lens system, for which the principal axes of the components are in the same straight line, that line is termed the optical axis of the system, or simply the axis. It should never be called the optic axis, which is a term used in crystallography.

principal meridian (United States public-land surveys).—See under *meridian*.

principal station.—See under *station*.

prismatic astrolabe.—See under *astrolabe*.

prismatic compass.—See under *compass*.

probable error.—See under *error*.

probable value: most probable value.—See under *value: most probable value*.

profile.—A section cut from the surface of the earth by a line moving along a fixed line as a directrix, and showing the line of intersection with that surface or with some underlying stratum.

Usually the moving line will be a vertical straight line, and the directrix will be a straight line or a regular curve (as the center line of a railroad or highway). The surface of intersection will be a plane surface or a regular curved surface that can be developed on a plane.

progress sketch.—A *map* or sketch showing work accomplished.

In *triangulation* and *traverse surveys*, each point established is shown on the progress sketch, and also lines observed over and *base lines* measured. In a *leveling survey*, the progress sketch shows the route followed and the towns passed through, but not necessarily the locations of the *bench marks*.

projection (surveying).—The extension of a line beyond the points which determine its character and position. The transfer of a series of *survey* lines to a single theoretical line by a series of lines perpendicular to the theoretical line.

In surveying a *traverse*, a series of measured short lines may be projected onto a single long line, connecting two main *survey* stations, and the long line then treated as a measured line of the *traverse*.

projection: map.—See under *map projection*.

protractor.—An instrument consisting of a plate marked with units of circular measure.

A protractor is used in laying out on a flat or curved surface an *angle* of desired magnitude; or in determining the magnitude of the *angle* made by two intersecting lines on a flat surface. Protractors are made in many sizes and forms to suit the purpose and convenience of the ones using them. See *protractor: three-arm protractor; coordinate protractor.*

protractor: coordinate.—A square-shaped *protractor* having graduations on two adjacent edges, with the center at one corner. It is equipped with a movable arm turning about the center, and graduated to show linear quantities on a given *scale*. The *protractor* is covered with a *grid* of the same *scale* and units as the arm.

In use, the arm is set for a given *azimuth* or *bearing*, and the length of a line marked on the arm: a reading of the *grid* at this point will give the *latitude* and *departure* of a line of the given length and *bearing*.

protractor: three-arm.—A full-circle *protractor*, equipped with three arms, the fiducial edges (extended) of which pass through the center of the circle. The middle arm is fixed, and reads 0° on the graduated circle. The other arms are movable, and their positions on the circle are read with the aid of *verniers*.

The two movable arms may be set to two *angles* observed between three fixed signals of known position, and the position of the point of observation obtained by a graphical solution of the *three-point problem*. Also called a station pointer.

public domain (United States).*—The territory ceded to the Federal Government by the Original Thirteen States, together with certain subsequent additions by cession, treaty, and purchase.

At its greatest extent, the public domain aggregated over 1,820,000,000 acres and included the present States of Alabama, Arizona, Arkansas, California, Colorado, Florida, Idaho, Illinois, Indiana, Iowa, Kansas, Louisiana, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Mexico, North Dakota, Ohio, Oklahoma, Oregon, South Dakota, Utah, Washington, Wisconsin, Wyoming, and the Territory of Alaska.

public land (United States).*—The portion of the *public domain (United States)* to which title is still vested in the Federal Government.

public land States.*—Those States and Territories created out of the *public domain (United States)*.

For list of public-land States see *public domain (United States)*.

Puerto Rico datum.—See under *datum*.

Q

quadrant.—Mathematics. A *sector* having an *arc* of 90°. Surveying. A *surveying* or astronomical instrument composed of a graduated *arc* about 90° in length, equipped with a sighting device (*alidade*).

The quadrant may be considered a form of *sector (surveying)*. Some quadrants combine both *surveying* and astronomical functions, having two *arcs*, one horizontal and one vertical.

quarter section (United States public-land surveys).—See under *section*.

quarter-quarter section (United States public-land surveys).—See under *section*.

R

radar.—The art of detecting by means of radio echoes the presence of objects, determining their direction and range, and employing the data obtained for navigational or military purposes.

Radar information is commonly obtained from the plan position indicator (PPI), a form of oscilloscope on which the direction and range of an echoing object are represented graphically.

radian.—See *angle (general)*, *(d)*.

random line.—A trial line run as nearly as circumstances permit from one survey station toward another survey station which cannot be seen from the first station.

The *error of closure* (amount by which the second station is missed) permits the computation of a *correction* to the initial *azimuth* of the random line; it also permits the computation of *offsets* from the random line to establish points on the line between the survey stations.

random traverse.—See under *traverse*.

range.—In general, two points in line with the point of observation.

The following are practical exemplifications of a range:

1. The line defined by the side of a building or by a fence may be extended visually to its intersection with a survey line: the point of intersection

thus determined is said to be in range with the side of the building or with the fence.

2. In hydrographic surveying, a range formed by two shore objects, if suitably located, aids in keeping a boat moving in a straight line; the line defined by the range.

3. In navigation, specially constructed aids mark ranges defining channels which are to be followed by vessels and keep them clear of dangers. Such ranges are often permanently marked by suitably lighted structures which are given identifying names, as: Honolulu Channel Front Light; Honolulu Channel Rear Light.

4. Boundary lines across water areas and boundary corners in water areas where permanent marks cannot be established, are sometimes defined by intersection of range lines or by a range line and distance from a mark, the range lines being marked by permanent *monuments* on the land.

range (United States public-land surveys).*—Any series of contiguous *townships* situated north and south of each other; also *sections* similarly situated within a *township.*

Ranges of townships are numbered consecutively east and west from a *principal meridian:* thus "range 3 east" indicates the third *range* or row of *townships* to the east from a *principal meridian.* The word *range* is used in conjunction with the appropriate *township* to indicate the *coordinates* of a particular *township* with reference to the *initial point;* thus "township 14 north, range 3 east" indicates the particular *township* which is the 14th *township* north of the *base line* and the 3rd *township* east of the *principal meridian.*

range finder.—An instrument for finding the distance from a single point of observation to other points at which no instruments are placed. See *tachymeter.*

In general, a range finder employs a very short *base line,* of fixed length, which is part of the instrument, and is utilized according to the principle of *triangulation.* The *precision* of the optical and other parts of the instrument is very great, but because of the small magnitude of the *angle* of intersection of the lines of sight at the object observed on, the distances obtained are not of a high order of *precision.*

range line (United States public-land surveys).*—An exterior boundary of a *township* extending in a north-south direction.

Réaumur scale.—A temperature scale in which 0° marks the freezing point and 80° the boiling point of water at 760 mm. barometric pressure.

In some of the earliest *geodetic* work, the Réaumur scale was used in stating the temperature of base-line measuring apparatus (*base apparatus*).

receiver (pendulum).—A heavy cast-metal box within which the *pendulum* is suspended and some auxiliary equipment placed when making observations for the *intensity of gravity.*

The receiver used with the *Mendenhall pendulum* is a heavy brass casting which can be made airtight and exhausted of air, mounted on foot screws for leveling, and provided with appliances for manipulating the *pendulums* and auxiliary equipment which are placed in it. It is provided with glass windows through which observations are made.

reciprocal of the flattening (of the earth).—See under *flattening of the earth.*

reconnaissance map.—See under *map.*

reconnaissance sketch.*—A drawing which resembles a *reconnaissance map* but is lacking in some *map* element.

reconnaissance survey.—See under *survey.*

recovery of station.—A survey *station* is considered as recovered when its mark (*monument*) is identified as authentic and proved to be occupying its original site.

The recovery of station is tested by checking the measurements for distance and *azimuth* (or *bearing*) from the station to a *reference mark. Witness marks* are aids to the recovery, but afford only secondary evidence of the position of the recovered mark. Sometimes, exact recovery requires that the original survey connections between the *station* and at least two adjacent *stations* of the same survey and class be tested and found unchanged.

rectangular coordinates.—See under *coordinates.*

rectangular polyconic map projection.—See under *map projection.*

rectifying latitude.—See under *latitude.*

reduced (parametric) latitude.—See under *latitude: parametric.*

reduction to center.—See under *center.*

reference mark.—A supplementary mark of permanent character close to a survey *station,* to which it is related by accurately measured distance and *azimuth* (or *bearing*).

The connection between a survey *station* and its reference mark(s) should be of sufficient *precision* and *accuracy* to permit the reestablishment of the *station* on the ground should its marks be destroyed, or the use of the reference mark in place of the survey *station* in the extension of surveys. Reference marks are used to define positions of boundary corners which may be so situated (as in water) that permanent marks cannot be placed exactly at the corners. See *corner: witness corner (United States public-land surveys).*

referencing.—The process of measuring the horizontal distances and directions (*azimuths* or *bearings*) from a survey *station* to nearby *landmarks, reference marks,* and other objects which may be used in the *recovery of the station.*

refraction: angle of.—See under *refraction of light.*

refraction: angle of incidence.—See under *refraction of light.*

refraction: astronomical.—The refraction by the earth's atmosphere of light from a source outside the atmosphere.

Light from a celestial body, as a star or planet, passes entirely through the atmosphere in reaching the earth, and follows a curved path which is concave to the surface of the earth. The *angle* between the direction of a ray where it enters the atmosphere and its direction at the point of observation is the astronomical refraction of the ray, or simply its refraction. It is also called celestial refraction. Its magnitude is greatest when the observed body is near the *horizon;* with slight irregularities, it decreases to a minimum near the *zenith,* being zero when the path of the ray is *normal* to the surfaces of the atmospheric layers. Astronomical refraction must be considered in many problems of astronomy, *surveying,* and navigation. See *refraction of light.*

refraction: atmospheric.—The *refraction of light* passing through the earth's atmosphere.

Atmospheric refraction includes both *astronomical refraction* and *terrestrial refraction.*

refraction: coefficient of.—The ratio of the *refraction angle* at the point of observation to the angle at the center of the earth subtended by the *arc* connecting the point of observation and the observed point.

refraction: index of.—The ratio of the sine of the *angle of incidence* to the sine of the *angle of refraction.*

When a ray of light passes from a vacuum into some medium or from some medium into a vacuum, the index of refraction is the absolute index of the medium. When a ray of light passes from one medium into another medium, the index is the relative index of those media. The index of refraction is slightly different for different wave lengths. This deviation, by refraction, of different wave lengths, is known as dispersion and, for any given medium, the amount of the deviation is a measure of the dispersive power of the medium. *Chromatic aberration* is overcome over a moderate range of wave lengths by using a composite lens (*achromatic lens*) composed of elements having different dispersive powers. A lens made achromatic for visual observation is not strictly achromatic for photographic work.

refraction: terrestrial.—The refraction by the earth's atmosphere of light from a terrestrial source.

The path of light from a terrestrial source is usually not far from horizontal; it passes through only the lower strata of the atmosphere, and suffers refraction throughout its entire length. The *angle of refraction*, or simply the refraction, of a survey line is the *angle* at the point of observation between the true *direction* of the observed object and the *direction* as shown by light coming from it (*direction* of object as seen).

Terrestrial refraction must be considered in many problems of *surveying*, and enters into some problems of astronomy and navigation which involve observations on terrestrial objects. Because the arrangement of the air strata is not exactly symmetrical in form and density, the path of a ray of light through the atmosphere is not a smooth curve in a *vertical plane*. Its curvature is greatest, however, in or close to a *vertical plane*, where its magnitude is of considerable importance in observations which are referred to the *zenith* or to the plane of the *horizon*, as are some *vertical angles* and *spirit levels*. Its effect is usually to make the apparent altitude of an object greater than its true *altitude*, though under special atmospheric conditions, this effect may be reversed.

In *triangulation*, a station which is normally just below the *apparent horizon* may, under certain conditions of the atmosphere and because of refraction, become visible for a short period of time and be observable. A line which can be observed over only with the aid of refraction is termed a *refraction line*. Refraction in a *direction* which is approximately horizontal is termed lateral refraction, and under some conditions can be of such magnitude as to seriously affect observed values of *horizontal* directions. A careful *reconnaissance* is required, especially for city surveys, to prevent the inclusion of lines so affected in a survey net. In some publications of the U. S. Coast and Geodetic Survey, terrestrial refraction is considered under the title of *atmospheric refraction*.

refraction angle.—That portion of an observed *zenith distance* which is due to the effect of *atmospheric refraction*.

The refraction angle may be taken as the difference between the observed and geometrically determined values of the *zenith distance*.

refraction line.—A line of sight to a *survey signal* which becomes visible only by the effect of *atmospheric refraction*.

Refraction lines are often over bodies of water, the observed signal normally being below the *apparent horizon*, but becoming visible at the time of greatest refraction during the day, when it appears to rise out of the water, disappearing back into the water as the refraction decreases.

refraction of light.—The change in direction of a ray of light passing obliquely from one medium into another, its speed in the two media being different.

The ray of light, before being refracted, is termed the incident ray; after refraction, the refracted ray. The *angle* between the incident ray and the *normal* to the surface separating the media at the point of refraction and on the same side of that surface as the incident ray is the angle of incidence; the corresponding *angle* between refracted ray and *normal* is the angle of refraction.

Refraction of light by the earth's atmosphere is termed *atmospheric refraction*, and is divided into two classes; *astronomical refraction*, also termed celestial refraction, and *terrestrial refraction*. Refraction of light must be considered in many problems of astronomy, *surveying*, and navigation. See *refraction: astronomical refraction; terrestrial refraction*.

relative position.—See under *position*.

relief.—See under *topography (or relief)*.

repeating theodolite.—See under *theodolite*.

repetition of angles.—The accumulation of a series of measures of the same *angle* on the horizontal circle of a *repeating theodolite* or surveyor's *transit*, in making which the final reading of one measure is used as the initial setting of the next measure of the *angle*. The observed value of the *angle* is obtained by dividing the total *arc* passed over by the number of observations.

representative fraction.—See under *map scale: fractional*.

Repsold base-line measuring apparatus.—See under *base apparatus*.

resection.—The determination of the horizontal position of a *survey station* by observed *directions* from the station to points of known position.

The most usual problem in resection is the determination of a point of observation by measuring two *angles* between three fixed points; this is the *three-point problem*, which is solved by computation (in *triangulation*), by mechanical means (with a *three-arm protractor* in hydrographic work), or graphically (on a plane-table survey). Its solution gives what is often termed a *fix*, a position for the point of observation. As employed in photogrammetry, resection refers to position determination from measurements on photographs.

residual error.—See under *error*.

resurvey.—See under *survey: resurvey*.

reticle (reticule).—A system of wires, hairs, threads, etched lines, or the like, placed *normal* to the axis of a telescope at its principal *focus*, by means of which the telescope is sighted on a star, signal, or target, or by means of which appropriate readings are made on some scale, such as a leveling or stadia rod.

reticle ring.—The ring across which the system of wires, hairs, threads, or the like of a *reticle* are stretched; or the ring which supports the glass *diaphragm* in case the reticle is a system of lines etched on glass.

reversible pendulum.—See under *pendulum*.

reversing point, micrometer screw (geodetic level).—That setting of the micrometer head at which the bubble remains in the center of the level vial, when the instrument is level and is *rotated* about its axis.

On some geodetic levels, a horizontal line on the micrometer head index piece indicates the position of the reversing point, within one turn of the micrometer screw, when the top of the micrometer-screw head is made level with it.

revolution.—Astronomy. A turning of a body about an exterior point or axis. See *rotation.* Mathematics. A turning of a geometrical figure about an axis.

We say that the earth *rotates* on its axis and revolves around the sun. However, in usage, such clear distinction between rotate and revolve is not always made with complete consistency. For example, in geodetic surveying, a *spheroid* adopted to represent the earth is termed an *ellipsoid* of revolution, though according to exact terminology it is an *ellipsoid* developed by the *rotation* of an ellipse around its minor axis. It may be desirable to disregard custom and speak of such a figure as an *ellipsoid* of rotation. The expression, *spheroid* of revolution, is of such general use that its use is continued in this publication.

rhumb line.*—A line which crosses successive *meridians* at a constant angle.

The *Mercator* is the only *map projection* on which a rhumb line is represented by a *straight line.* Other names for rhumb line are: loxodrome, loxodromic curve, equiangular spiral, and *Mercator track.*

right ascension.—The *angle* between the plane of the *hour circle* passing through a celestial body and the plane of the *hour circle* passing through the *vernal equinox.*

Right ascension may be measured by the *angle* at the celestial pole between the tangents to the *hour circles* of the body and of the *vernal equinox,* or by the *arc* of the *equator* intercepted by those *hour circles.* Right ascension is measured eastward from the *vernal equinox* through 24 hours (360°). It corresponds to *longitude* on the earth, and with *declination* forms a pair of *coordinates* which defines the position of a body on the *celestial sphere.*

right bank.—See under *bank of stream.*

river bed.—See under *bed of stream.*

river crossing (leveling).—Carrying a *line of levels* across a stream or other body of water, when no suitable bridge is available and the width of the body of water is greater than the maximum allowable length of sight for the leveling, requires a special series of observations which taken collectively is known as a river crossing.

rod correction (leveling).—See under *correction.*

rotation.—Astronomy. A turning of a body about a self-contained axis. See *revolution.* Surveying. A turning of an instrument or part of an instrument about an axis.

The earth rotates on its axis. The *alidade* of a *theodolite* rotates about a vertical axis.

run of micrometer.—See under *micrometer.*

running (leveling).—A continuous series of measured differences of elevation, made *set-up* by set-up in one direction along a *section* of a *line of levels,* which results in a measurement of the difference of elevation between the *bench marks* or other points, either temporary or permanent, at the ends of the section.

rural delivery map.—See under *map.*

S

sag correction, tape.—See under *tape.*

St. George Island datum.—See under *datum.*

St. Hilaire Method (Method of Marcq St. Hilaire).—An adaptation of the *Sumner line* method of position determination which employs assumed *altitudes* (*vertical angles*) in the computation of an astronomical position, and applies a simple *correction* for the difference between the observed and assumed values of the *altitudes.*

This method simplifies the usual method of computing a position from *Sumner lines;* it is especially effective and simple near the geographic poles. It was invented in 1874 by Marcq de St. Hilaire, a French naval officer.

St. Michael datum.—See under *datum.*

St. Paul Island datum.—See under *datum.*

Sanson-Flamsteed map projection.—See under *map projection: sinusoidal.*

scale: equivalent map.—See under *map scale.*

scale: fractional map.—See under *map scale.*

scale: graphic (or bar) map.—See under *map scale.*

scale: map.—See under *map scale.*

scale factor.—A multiplier for reducing a distance obtained from a *map* by computation or scaling to the actual distance on the *datum* of the *map.* Also, in the *State coordinate systems,* scale factors are applied to *geodetic* lengths to obtain *grid lengths,* or to *grid lengths* to obtain *geodetic* lengths; both are lengths on a *sea-level datum,* but the *grid lengths* are affected by the distortion of the *map projection.*

school and bus route map.—See under *map.*

Schott base-line measuring apparatus.—See under *base apparatus.*

sea level.—In general, the surface of the sea used as a reference for *elevation.* In *surveying* and mapping, a curtailed form of *mean sea level.*

In *surveying* and mapping, the use of sea level should be avoided; but if used, it should be with the meaning of *mean sea level.*

sea level datum.—A determination of *mean sea level* that has been adopted as a standard *datum* for heights. The sea level is subject to some variations from year to year, but as the permanency of any datum is of prime importance in engineering work, a sea level datum after adoption should in general be maintained indefinitely even though differing slightly from later determinations of mean sea level based upon longer series of observations.

The sea level datum now used for the U. S. Coast and Geodetic Survey level net is officially known as the "Sea Level Datum of 1929," the year referring to the last general adjustment of the net. The datum itself may be considered as an adjustment based upon tide observations taken at various tide stations along the coasts of the United States over a number of years. See also under *mean sea level.*

sea mile.—See under *mile: nautical.*

secant method (United States public-land surveys).*—A method of determination of the *parallel* of *latitude* for the survey of a *base line* or *standard parallel* by *offsets* from a *great circle line* which cuts the *parallel* at the first and fifth mile corners of the *township* boundary.

The secant method is a modification of the *tangent method,* so arranged that minimum *offsets* need be made from the projected *great circle line* to the *parallel;* at the first and fifth mile stations on the secant the *offsets* are zero; between those stations the *offsets* are measured to the south; before and after those stations the *offsets* are measured to the north.

secondary triangulation.—See under *triangulation.*

second-order bench mark.—See under *bench mark.*

second-order control surveys.—See under *second-order work (control surveys).*

second-order leveling.—See under *leveling.*

second-order traverse.—See under *traverse.*

second-order triangulation.—See under *triangulation.*

second-order work (control surveys).—The designation given survey work of next-to-the-highest order of *accuracy* and *precision.* See *traverse; triangulation;* and *leveling.*

section (leveling).—That portion of a *line of levels* which is recorded and abstracted as a unit.

A section always begins and ends on a *bench mark,* either temporary or permanent, when in the main *line of levels* or on a *spur line of levels.* In the case of a *spur* to a point the *elevation* of which is determined by means of an *extra foresight,* the section must begin on a temporary or permanent *bench mark* and end on the point on which the *leveling rod* was held when the *extra foresight* was taken.

section (United States public-land surveys).*—The unit of subdivision of a *township;* normally a quadrangle 1 mile square, with boundaries conforming to *meridians* and *parallels* within established limits, and containing 640 acres as near as may be.

A normal *township* is divided into 36 sections by lines 1 mile apart measured from the southern and eastern boundaries; any excess or deficiency in measurement is placed in the northern *tier* or western *range* of sections. The sections within a normal *township* are numbered consecutively commencing with number 1 in the northeast section and progressing west and east alternately with progressive numbers in the *tiers,* to number 36 in the southeast section.

section: fractional (United States public-land surveys).*—A *section* containing appreciably less than 640 acres, usually due to invasion by a segregated body of water, or by other land which cannot properly be surveyed or disposed of as part of that *section.*

Sections are also frequently rendered fractional in closing the *surveys* on the north and west boundaries of the *township,* for the reason that deficiencies in measurement caused by *error* of *survey* or *convergence of meridians* are placed in the half mile closing against these *township* boundaries.

section: half (United States public-land surveys).*—One-half of a normal *section,* formed by dividing a *section* into two parts by a line connecting opposite *quarter-section corners,* and containing 320 acres as near as may be.

The half section is a unit of description of the *public lands;* thus the "east half, section 10" is the legal description of that portion of *section* 10 of a given *township* lying east of the north-south *center line* of the *section.*

section: quarter (United States public-land surveys).*—One-fourth of a normal *section,* formed by dividing a *section* into four parts by lines connecting the opposite *quarter-section corners,* and containing 160 acres as near as may be.

The quarter section is a unit of description of the *public lands;* thus the "northeast quarter, section 10" is the legal description of that portion of section 10 of a given *township* lying east of the north-south *center line* and north of the east-west *center line* of that *section.*

section: quarter-quarter (United States public-land surveys).*—One-sixteenth of a normal *section,* formed by dividing a *quarter section* into four parts by lines connecting the midpoints of opposite sides, and containing 40 acres as near as may be.

The quarter-quarter section is a unit of description of the *public lands;* thus the "northeast quarter of the northeast quarter, section 10" is the legal description for that portion of section 10 of a given *township* lying east of the north-south *center line* and north of the east-west *center line* of the northeast quarter of that *section.*

sector.—Mathematics. A geometrical figure bounded by an *arc* and two radii. Surveying. An instrument composed of a graduated *arc* equipped with a sighting device (*alidade*).

In *surveying,* the sector and the *quadrant* were the immediate predecessors of the *theodolite,* both being mentioned in reports of early *geodetic* surveys in connection with the measurement of horizontal angles. These instruments were constructed with *arcs* having radii several feet in length. Combined with other words, sector is used to designate certain *map* features, as red sector; and special types of instruments, as *zenith sector; track sector.*

sector: track.—See under *track sector.*

sector: zenith.—An astronomical instrument for measuring *zenith distances,* in which a plumb line is read against a short vertical *arc.* Also, a modern form of such an instrument, employing *spirit levels* and an *ocular micrometer.*

In its early form, before the invention of the *telescope,* the zenith sector consisted of a *quadrant* with plumb-line control. With the coming of the *telescope,* zenith sectors used in astronomical work in connection with surveying operations employed *telescopes* up to five or six feet in length with short vertical *arcs,* the *vertical angle* being read by means of a plumb line suspended from the horizontal axis of the instrument.

A later form of zenith sector, employing *spirit levels* and an *ocular micrometer,* is a *precision instrument.* These instruments were used in measuring *zenith distances* and differences of *zenith distances* of stars close to the *zenith.* In making determinations of *astronomic latitude,* the zenith sector has been superseded by the *zenith telescope.*

secular parallax.—See under *parallax: diurnal parallax.*

selenotrope.—An instrument similar to the *heliotrope,* but adapted for reflecting moonlight for signal purposes.

The selenotrope differs from the heliotrope only in the greater size of the mirror used, being operated in exactly the same way. In tests made in 1883 and 1887, selenotropes with mirrors of the sizes stated furnished satisfactory lights on which to observe at the following distances: 22 miles, 6- by 6-inch mirror; 48 miles, 6- by 8-inch mirror; and 70 miles, 8- by 10-inch mirror.

set-back.—The horizontal distance from the *fiducial mark* on the front end of a tape or part of tape which is in use at the time back to the point on the ground mark or monument to which the particular measure is being made.

A set-back is usually a very small distance in base-line measures where tape supports in the form of stakes are placed in advance of the measure; if the distance between the stakes is too small, the tape will over-run the stakes, and set-backs must be measured. If portable supports, such as bucks, are used, there will seldom be need for measuring set-backs. Set-backs are minus corrections to tape distances. In the work of the U. S. Coast and Geodetic Survey, the use of set-backs is avoided. See *set-up.*

set-up.—The horizontal distance from the *fiducial mark* on the front end of a tape or part of tape which is in use at the time, measured in a forward direction to the point on the ground mark or *monument* to which the particular measure is being made. Also, a surveying instrument in position at a point of observation.

A set-up is usually a very small distance in base-line measures where tape supports in the form of stakes are placed in advance of the measures; if the distance between the stakes is too great, the tape will not reach from stake to stake, and set-ups must be measured. If portable supports, such as bucks, are used, there will seldom be need for measuring set-ups. Set-ups are plus *corrections* to tape distances. See *set-back*.

set-up (leveling).—The actual physical placing of the *leveling instrument* over an *instrument station*.

The terms *instrument station* and set-up, especially in leveling, are often used interchangeably with little loss of accuracy of statement. However, if any distinction is to be made, set-up is considered to be the instrument when mounted or set up over the *instrument station* or point on the ground which is in the vertical axis of rotation of the instrument.

sextant.—A hand instrument for measuring the *angle* between two objects in the plane defined by the two objects and the point of observation, and based on the optical principle that if a ray of light suffers two successive reflections in the same plane by plane mirrors, the *angle* between the first and last directions of the ray will be twice the *angle* between the plane mirrors.

The sextant has a graduated arc of 60°, from which it derives its name. Each degree division represents a 2° *angle* between the first and last directions of the ray of light, and is so marked: the 60° arc is marked 120°. The last reflection of the ray is made parallel with the direction of the second object, hence the *angle* between the two objects, one seen by double reflection and the other viewed directly, is registered on the sextant. The instrument is used in navigation for measuring *elevations* of celestial objects, in hydrographic surveying for measuring *horizontal* angles at a point in a moving boat between shore objects, and wherever instability of support makes it impossible to use a *theodolite* or *transit*. The sextant has been in use since around 1730. It is capable of use as a *precision* instrument.

sextant: bubble sextant.—A *sextant* in which the bubble of a *spirit level* serves as the *horizon*.

A simple form of bubble sextant was designed by R. E. Byrd and used by him in aerial navigation, on expeditions to the North and South Poles and on other arctic and antarctic expeditions. It has a *spirit level* with a circular bubble attached to the *sextant* quite close to the horizon glass; the *elevation* of a celestial object is measured by bringing its image into contact with the image of the bubble as seen in the horizon glass.

ship-shore triangulation.—See *triangulation: ship-shore*.

shoran.—A pulse-type electronic ranging system originally designed for the positioning of bombing aircraft and later adapted for use in aerial photography, geophysical exploration, hydrography, and long-range geodetic surveying.

Fundamentally, the system consists of a mobile transmitter-receiver-indicator unit and a fixed receiver-transmitter unit (transponder). Pulses are sent from the mobile transmitter and returned to the originating point by the transponder. The indicator measures the time interval required for travel of a pulse between stations and converts this information into distance to the nearest thousandth of a mile. Shoran range is approximately limited to direct-path transmission as a consequence of the carrier frequency used (200–300 megacycles).

shore.—The land which is covered and uncovered by the rise and fall of the normal *tide*.

It is the strip of land between the *mean high-water* and *mean low-water lines*. In its strictest use, the term applies only to land along tidal waters.

shore line.—The land-side *boundary line* of the *shore*; the *mean high-water line*.

Along a river, the shore line is the line along the river bank which is washed by the water without overflowing it.

shore of stream.—The area between the *bank* of a stream and its *low-water line*.

side equation.—See under *equation*.

side shot.—A reading or measurement from a survey *station* to locate a point which is not intended to be used as a base for the extension of the *survey*.

A side shot is usually made for the purpose of determining the *position* of some object which is to be shown on the *map*.

sidereal day.—See under *day*.

sidereal focus.—See under *focus*.

sidereal month.—See under *month*.

sidereal time.—See under *time*.

sidereal time: Greenwich.—See under *time*.

sidereal time: local.—See under *time*.

sidereal year.—See under *year*.

signal: longitude.—A sign indicating a time event, observable at different stations, and used in comparing local times of those stations, and determining the difference of their *longitudes*. See *longitude* (various methods).

signal: survey.—A natural or artificial object or structure whose horizontal and sometimes vertical position is obtained by *surveying* methods.

Signals are given special designations according to the kind of *survey* in which they are determined, or which they may later serve.

signal: triangulation.—A rigid structure erected over or close to a *triangulation* station and used for supporting instrument and observer, or target, or both instrument and observer and target, in a *triangulation* survey. Also any object, natural or artificial, whose position is obtained in a *triangulation* survey.

The term may be applied to a structure whose position is determined by *triangulation*, but whose primary purpose is to serve later in a *hydrographic* or *topographic survey*, when it may become known as a hydrographic or topographic signal.

simple pendulum.—See under *pendulum*.

simultaneous double line.—See under *level line: simultaneous level line*.

simultaneous level line.—See under *level line*.

sinusoidal map projection.—See under *map projection*.

siphon barometer.—See under *barometer*.

slope stake.—A stake set on the line where a finished side slope of an excavation (cut) or embankment meets the original ground surface.

small scale.—See under *map scale: fractional*.

solar attachment.—An auxiliary instrument which may be attached to an engineer's *transit*, permitting its use as a *solar compass*.

solar compass.—See under *compass*.

solar day.—See under *day*.

solar focus.—See under *focus: sidereal focus*.

solar parallax.—See under *parallax*.

solar time.—See under *time: apparent solar time; mean solar time*.

solar transit.—An engineer's *transit* designed for use in place of a *solar compass*.

solenoid.—A coil of wire, often helical in form, which becomes an electromagnet when an electric current is passed through it.

When tests show an *invar pendulum* to be magnetized beyond a prescribed limit, a solenoid is used to demagnetize it. The standard equipment for a party engaged in determinations of *gravity* includes a suitably mounted solenoid, with compass needle, battery, and control switches.

solid angle.—See under *angle.*

solstice.—A point on the *ecliptic* midway between (90° from) the *equinoxes.* See *solstice: summer; solstice: winter.*

solstice: summer.—The point on the *ecliptic,* north of the *equator* and midway between (90° from) the *equinoxes.*

The summer solstice is the point where the sun attains its greatest north *declination,* a position which marks the beginning of the season of summer.

solstice: winter.—The point on the *ecliptic,* south of the *equator* and midway between (90° from) the *equinoxes.*

The winter solstice is the point where the sun attains its greatest south *declination,* a position which marks the beginning of the season of winter.

solstitial colure.—See under *colure.*

southing.—See under *latitude: difference of latitude (plane surveying).*

speaking rod.—See under *leveling rod (general).*

special-purpose map.—See under *map.*

spherical aberration.—See under *aberration of light (optics).*

spherical angle.—See under *angle.*

spherical coordinates.—See under *coordinates.*

spherical excess.—The amount by which the sum of the three *angles* of a triangle on a sphere exceeds 180°.

In *geodetic* work, in the computation of triangles, the difference between *spherical angles* and *spheroidal angles* is generally neglected, *spherical angles* are used, and *Legendre's Theorem* applied to the distribution of the spherical excess. That is, approximately one-third of the spherical excess of a given spherical triangle is subtracted from each *angle* of the triangle.

spheroid.—In general, any figure differing but little from a sphere. In *geodesy,* a mathematical figure closely approaching the *geoid* in form and size, and used as a surface of reference for *geodetic surveys.*

In *geodetic surveying,* the spheroid is usually an ellipsoid of revolution, but there is some disadvantage in using the term spheroid as synonomous with such a figure. Until the adoption of the International Gravity Formula (Stockholm, 1930), none of the *gravity* formulas in general use corresponded to an exact ellipsoid of revolution. Helmert's formula of 1917 and some later ones included a term that implied a spheroid with an elliptical *equator,* and *meridians* which were not exact ellipses. Ellipsoids of three unequal axes and spheroids with non-elliptical *meridians* have been proposed by geodesists to secure better representation of observed *deflections of the vertical.* The mathematical difficulties of fitting *triangulation* to any such surface have firmly established the use of an ellipsoid of revolution for that purpose. A spheroid which corresponds to an ellipsoid of revolution may be defined by stating the lengths of the semiaxes (a and b) of the generating ellipse, or the length of one of the semiaxes and the *flattening* (*ellipticity*) $[(a-b)/a]$ of the ellipse.

A spheroid serves as a base for the mathematical reduction (*correlation* and *coordination*) of surveying observations where account must be taken of the curvature of the earth's surface. It is such a figure as would be produced by an ellipse revolving around its minor axis, that is, an oblate ellipsoid. A particular spheroid may be defined by stating the lengths of its semiaxes, a and b, or the length of one semiaxis and the *flattening* (ellipticity), $(a-b)/a$. In the *geodetic* work of this country, the following spheroids have been used: the Bessel spheroid of 1841, for which $a=6{,}377{,}397.2$ meters and $b=6{,}356{,}079.0$ meters; the Clarke spheroid of 1866, adopted in 1880, and in continuous use since that time. For it, $a=6{,}378{,}206.4$ meters; $b=6{,}356{,}583.8$ meters.

Of interest also is the Hayford spheroid, based upon observations over this entire country, in computing which account was taken of the local *deflections of the vertical* by applying corrections for the effects of *topography* and *isostatic compensation.* The Hayford spheroid is defined by $a=6{,}378{,}388$ meters; $b=6{,}356{,}909$ meters. In 1924, the General Assembly of the Section of Geodesy of the International Geodetic and Geophysical Union, meeting in Madrid, adopted the Hayford spheroid as the basis for the International Ellipsoid of Reference, defined as follows: $a=6{,}378{,}388$ meters; *flattening* (ellipticity), $(a-b)/a=1/297$; and by computation, $b=6{,}356{,}911.946$ meters.

While for reasons of expediency, the International Ellipsoid of Reference has not been adopted for survey work in this country, it has considerable scientific value and tables for its use have been computed and published.

spheroid: eccentricity of.—See under *eccentricity of spheroid.*

spheroid: ellipticity of.—See under *flattening of the earth.*

spheroid: lines on a.—Any direct line between two positions on a *spheroid,* represented by two points on the earth.

Such a line may be one of mathematical definition, or it may result from a direct *survey* between the points on the earth. Eight such lines, connecting two points, A and B, are listed in U. S. Coast and Geodetic Survey Report for 1900, pages 369–370, as follows:

(a) A *normal section line* from A to B.

(b) A *normal section line* from B to A.

(c) A *curve of alignment.*

(d) A *geodetic line.*

(e) A forward straight line starting in the plane of the *normal* through A and through B, and in advancing keeping B constantly sighted.

(f) A line similar to (e) above, but starting in the plane of the *normal* through B and through A, and in advancing keeping A constantly sighted.

(g) A forward and backward sight line over limited distances, starting from A.

(h) A forward and backward sight line over limited distances, starting from B.

(Lines (a), (b), (c), and (d) are defined elsewhere.)

spheroidal angle.—See under *angle.*

spheroidal excess.—The amount by which the sum of the three *angles* of a triangle on a *spheroid* exceeds 180°.

In *geodetic* work, *spherical angles* are used instead of *spheroidal angles,* the difference between such *angles* being quite small for the largest triangles, and considered negligible for ordinary triangulation work.

spiral curve.—See under *curve.*

spirit level.—See under *level.*

spirit level axis.—See under *level axis.*

spirit level, chambered.—See under *level.*

spirit leveling.—See under *leveling*.

spur (leveling).—See under *line of levels*.

spur line of levels.—See under *line of levels*.

stadia.—A graduated rod used in the determination of distance by observing the intercept on the rod subtending a small known *angle* at the point of observation.

In practice, the *angle* is usually defined by two fixed lines in the *reticle* of a *telescope* (*transit* or *telescopic alidade*). The term stadia is also used in connection with *surveys* where distances are determined with a stadia, as, stadia survey, stadia method, stadia distance, etc.; also used to designate parts of instruments used, as, stadia wires. In its strictest use, stadia refers to the graduated rod.

stadia (length).—The plural form of stadium, a Greek measure of length somewhat greater than 600 feet.

stadia constant (leveling).—See under *constant*.

stadia interval (leveling).—See under *interval*.

Stampfer level.—See under *leveling instrument*.

standard.*—An exact value, or concept thereof established by authority, custom, or common consent, to serve as a model or rule in the measurement of quantity, or in the establishment of a practice or procedure.

Standard, as it pertains to any specific term, is considered in the supplementary statement of that term.

Standard (California) astronomical datum of 1885.—See under *datum*.

standard elevation.—See under *elevation*.

standard line (United States public-land surveys).*—Any *base line, standard parallel, principal meridian*, or *guide meridian*.

The term standard line is not in general use.

standard of length.—A physical representation of a linear *unit* that is approved by competent authority.

A standard of length is not independent of temperature, pressure, and other physical conditions to which it is subjected, but is an exact embodiment of the *unit* which it represents only under definite, prescribed conditions. See *meter: International Prototype Meter*.

Standards of length are classified according to the *accuracy* and *precision* of their representation of the given *unit*, and these are prescribed by their intended use and are designated accordingly, as follows:

1. Primary standards. International and national prototype *standards* of the highest possible *accuracy* and *precision*.

2. Secondary standards. Laboratory *standards* that are compared directly with the national *standards*.

3. Reference standards. *Standards* suitable for use in the construction of *precision* apparatus to be used in scientific investigations.

4. Working standards. *Standards* suitable for all ordinary *precision* work, as in college laboratories, the general manufacture of *precision* instruments, and for the use of State and city sealers of weights and measures.

5. Commercial standards. *Standards* satisfying the requirements of local sealers of weights and measures, drafting, machine work, etc.

Standards of length are also classified according to their design: 1. Line standards. A *standard* in which the *unit* of length is defined as the distance between lines or marks on the surface of the *standard*, under prescribed conditions. 2. End standard. A *standard* in which the *unit* of length is defined as the distance between the end surfaces of the *standard*, under prescribed conditions. Also termed a contact standard.

standard parallel (United States public-land surveys).—See under *parallel*.

standard survey.—See under *survey*.

standard time.—See under *time*.

standard topographic map of the United States.—See under *map: Topographic Map of the United States*.

standardization.—The comparison of an instrument or device with a *standard* to determine the value of the instrument or device in terms of an adopted *unit*.

A tape is standardized when the distance between its *fiducial marks* in terms of a *unit* of length is determined by comparing it, under prescribed conditions, with a *standard* which represents that *unit*. See *calibration*. A *pendulum* is standardized by determining its period at a base station at frequent intervals of time, care being taken each time to swing the *pendulum* under as nearly the same conditions as practicable, and correcting the results to the adopted references of temperature, air pressure in the *receiver, amplitude of vibration*, and *flexure*.

standardization.—(Alternate definition.) The determination of the physical characteristics of a gage or measuring device by comparing it with a *standard*.

A gage or measuring device is standardized so that measures made with it may be reported and used in terms of the *unit* which the *standard* exemplifies. The term "standardization" may include the determination of a quantity which is required in reducing the direct results of a standardization to corresponding values under changing conditions. For example, when a *base tape* is standardized, its length is determined at a definite temperature, under prescribed conditions of tension and support. Its use in the field requires also that its *coefficient of thermal expansion* be known.

State base map.—See under *map*.

State coordinate systems.—The *plane-rectangular coordinate* systems established by the U. S. Coast and Geodetic Survey, one for each State in the Union, for use in defining *positions* of *geodetic* stations in terms of *plane-rectangular* (x and y) *coordinates*.

Each State is covered by one or more zones, over each of which is placed a *grid* imposed upon a *conformal map projection*. The relationship between the *grid* and the *map projection* is established by mathematical analysis. Zones of limited east-west dimension and indefinite north-south extent have the *transverse Mercator map projection* as the base for the State coordinate system; while zones for which the above order of magnitude is reversed use the *Lambert conformal conic map projection* with two *standard parallels*. For a zone having a width of 158 *statute miles*, the greatest departure from exact *scale* (scale error) is 1 part in 10,000. Only *adjusted positions* on the *North American datum of 1927* may be properly transformed into *plane coordinates* on a State system. All such *geodetic positions* which are determined by the U. S. Coast and Geodetic Survey are transformed into State *plane-rectangular coordinates* on the proper *grid*, and are distributed by that Bureau with the *geodetic positions*. State *plane coordinates* are extensively used in recording *land surveys*, and in twenty-two States such use has received approval by legislative enactment.

State map.—See under *map*.

static map.—See under *map*.

station.—A definite point on the earth whose location has been determined by *surveying* methods. A point on a *traverse* over which an instrument is placed (a *set-up*). Also, on a *traverse,* a length of 100 feet measured on a given line, broken, straight, or curved.

A station may or may not be marked on the ground. A station is usually defined by the addition of a term which describes its origin or purpose, such as *triangulation station,* topographic station, magnetic station, etc. A station is often marked on the ground by a *monument* of special construction, or by a natural or artificial structure.

station: instrument (leveling).—The point over which a *leveling instrument* is placed for the purpose of taking a *backsight,* a *foresight,* and such *extra foresights* as may be necessary from that instrument station. See, also, *set-up.*

Except in rare instances, the instrument stations in a *line of levels* are not marked points such as traverse *stations,* triangulation *stations,* etc.

station: intersection.—An object whose horizontal *position* is determined by observations from other survey stations, no observations being made at the object itself.

Where the object is observed from only two *stations,* the position is termed a "no check position," as there is no proof that such observations are free from *blunders.* Intersection stations are either objects which it would be difficult to occupy with an instrument, or survey signals whose positions can be determined with sufficient *accuracy* without being occupied.

station: principal.—A *station* through which basic data are carried in the extension of a survey system.

Also called a main-scheme station, a principal *station* serves primarily for the continued extension of a *survey.* This requires a higher order of *accuracy* and *precision* in its determination than if its purpose were limited to the control of local surveys or the establishment of *supplementary stations.*

station: subsidiary.—A *station* established to overcome some local obstacle to the progress of a *survey,* and not to determine position data for the *station* point.

The term subsidiary station is usually applied to *A-stations* of a *traverse survey.* Subsidiary stations are usually temporary in character and not permanently marked. If serving the additional purpose of supplying control for a local *survey,* such a *station* may be permanently marked and it is then a *supplementary station.*

station: supplementary.—An auxiliary survey *station,* established to increase the number of control *stations* in a given area, or to place a *station* in a desired location where it is impracticable or unnecessary to establish a *principal station.*

Supplementary stations are permanently marked, and are established with an *accuracy* and *precision* somewhat lower than is required for a *principal station,* since they do not serve as bases from which extensive *surveys* are run. See *station: subsidiary.*

station adjustment.—See under *adjustment.*

station error.—See under *deflection of the plumb line.*

station pointer.—See under *protractor: three-arm protractor.*

statute mile.—See under *mile.*

Stephenson leveling rod.—See under *leveling rod.*

steradian.—See under *angle: solid.*

stereographic horizon projection.—See under *map projection: stereographic map projection.*

stereographic map projection.—See under *map projection.*

stereographic meridional projection.—See under *map projection: stereographic map projection.*

stereographic polar projection.—See under *map projection: stereographic map projection.*

strength of figure (triangulation).—The comparative *precision* of computed lengths in a *triangulation net* as determined by the size of the *angles,* the number of *conditions* to be satisfied, and the distribution of *base lines* and points of *fixed position.*

Strength of figure in *triangulation* is not based on an absolute scale but rather is an expression of relative strength. The number expressing the strength of a *triangulation* figure is really a measure of its weakness, since the number determined by formula increases in size as the strength decreases.

The strength of figure is derived from that portion of the formula for *probable error* of a triangle side, which is independent of the *accuracy* of the observations, as follows:

$$\frac{N_d-N_c}{N_d}\sum\left[\delta_A^2+\delta_A\delta_B+\delta_B^2\right]$$

in which N_d and N_c are the numbers of directions observed and of *conditions* to be satisfied, and δ_A and δ_B are the rates of change of the sines of the *distance angles* A and B, usually expressed by the differences of the logarithms of the sines for a difference of 1″ in the *angles,* the sixth decimal place being the unit place.

By summing up the values obtained by formula for the simple figures composing a *triangulation net,* the strength of figure of the net is obtained. As a *triangulation net* is usually composed of several different systems of simple figures, comparable values of the different systems are obtained, and the strongest route can then be selected through which to carry a computation of length.

Reconnaissance for a proposed *triangulation net* is usually executed under instructions which specify limiting values of strength of figure for the best and second-best chains of triangles between adjacent *base lines,* the sites for stations and for *base lines* being selected accordingly. Where desirable, the length of section may be reduced by the insertion of an additional *base line,* and the numbers representing the strength of figure reduced accordingly.

stride.—The distance a pedestrian moves in taking two steps.

Formerly, the stride and the *pace* were largely synonomous; if there was a difference, it was that the stride was a long *pace.* The above definition conforms to present-day teaching, and satisfies the need for a term expressing the distance moved in taking a double step. Hence, one stride equals two *paces.*

striding level.—See under *level.*

subsidiary station.—See under *station.*

summer solstice.—See under *solstice.*

Sumner line (line of position).—A short portion of a *circle of position* represented as a *straight line.*

The Sumner line was named for Captain Thomas H. Sumner, an American sea captain, who discovered its use in 1843. The St. Hilaire Method is a special adaptation of the use of the Sumner line in navigation.

sun compass.—See under *compass.*

supplement of angle.—See under *angle.*

supplemental posts for survey monuments.—See under *identification posts.*

supplementary bench mark.—See under *bench mark.*

supplementary station.—See under *station.*

survey.—1. The orderly process of determining data relating to any physical or chemical characteristics of the earth. 2. The associated data obtained in a survey (1, above). 3. An organization engaged in making a survey (1, above).

1. The list of orderly processes which may be properly called surveys is long; it may be divided into

classes according to the type of data obtained, the methods and instruments used, the purposes to be served, etc. Examples: *geodetic survey, topographic survey, hydrographic survey, land survey, geologic survey,* geophysical survey, soil survey, *mine survey, engineering survey,* etc.

2. The data obtained in a particular project may be designated by the name of the project, as, "the topographic survey of the District of Columbia."

3. An organization making a survey is often given an official name which includes the word survey; examples, "The United States Geological Survey," "The Massachusetts Geodetic Survey."

survey: cadastral.*—A *survey* relating to *land boundaries* and subdivisions, made to create units suitable for transfer or to define the limitations of title.

Derived from "cadastre," meaning register of the real property of a political subdivision with details of area, ownership, and value, the term cadastral survey is now used to designate the *surveys* of the *public lands* of the United States, including retracement *surveys* for the identification, and *resurveys* for the restoration, of property lines; the term may also be applied properly to corresponding *surveys* outside the *public lands,* although such *surveys* are usually termed *land surveys* through preference.

survey: engineering.*—A *survey* executed for the purpose of obtaining information that is essential for planning an engineering project or development and estimating its cost.

The information obtained may, in part, be recorded in the form of an *engineering map.*

survey: exploratory.*—A *survey* executed for the purpose of obtaining general information concerning areas about which such information was not, theretofore, a matter of record.

The U. S. Geological Survey executes exploratory *surveys* in remote regions of Alaska which are used in the construction of *maps* on *scales* of 8 or more *miles* to an *inch.*

survey: geodetic.—1. A *survey* in which account is taken of the figure and size of the earth. 2. An organization engaged in making geodetic surveys.

a. Geodetic surveys are usually prescribed where the areas or distances involved are so great that results of desired *accuracy* and *precision* can be obtained only by the processes of geodetic surveying.

b. The Massachusetts Geodetic Survey is an example of an organization engaged in making geodetic surveys.

survey: geographic.—A general term, not susceptible of defined limitation, covering a wide range of *surveys* lying between and merging into *exploratory surveys* on the one hand and basic *topographic surveys* on the other.

Geographic surveys usually cover large areas, are based on coordinated control, and are used to record physical and statistical characteristics of the area surveyed.

survey: geologic.—A *survey* or investigation of the character and structure of the earth, of the physical changes which the earth's crust has undergone or is undergoing, and of the causes producing those changes.

survey: geological.—A general term used to designate an organization making *geologic surveys* and investigations.

survey: hydrographic.—A *survey* having for its principal purpose the determination of data relating to bodies of water.

A hydrographic survey may consist of the determination of one or several of the following classes of data: depth of water and configuration of bottom; directions and force of currents; heights and times of tides and water stages; location of fixed objects for *survey* and navigation purposes.

survey: inventory.—A *survey* for the purpose of collecting and correlating engineering data of a particular type (or types) over a given area.

An inventory survey may be recorded on a *base map.*

survey: land.—See under *surveying: land surveying.*

survey: location.—The establishment on the ground of points and lines in positions which have been previously determined by computation or by graphical methods.

The plans for an engineering project (road, canal, etc.) are prepared in the office from *survey* data obtained in the field. These plans form a paper location, and are the basis for the location survey.

survey: mine.—A *survey* to determine the positions and dimensions of underground passages of a mine; also of the natural and artificial features, surface and underground, relating to the mine.

The data include both horizontal and vertical *positions,* lengths, and directions (slopes) of tunnels; topographic and geological characteristics of the particular vicinity; ownership of the land and of the mine; etc.

survey: plane.—See under *surveying: plane surveying.*

survey: preliminary.—The collection of survey data on which to base studies for a proposed project.

A triangulation reconnaissance is a preliminary survey, securing data on which to base plans for the execution of the *triangulation.*

survey: reconnaissance.*—A *preliminary survey.*

A reconnaissance survey is usually executed rapidly and at relatively low cost. The information obtained is recorded, to some extent, in the form of a *reconnaissance map* or *sketch.* The form reconnaissance is preferred to reconnoissance.

survey: resurvey.—A retracing on the ground of the lines of an earlier *survey,* in which all points of the earlier *survey* that are recovered are held fixed and used as a control.

If too few points of the earlier *survey* are recovered to satisfy the control requirements of the resurvey, a new *survey* may be made. A resurvey is related directly to an original *survey,* though several resurveys may interpose between them. The terms original *survey,* resurvey, and new *survey* are of considerable significance in *land surveying.*

survey: standard.—A *survey* which, in *scale, accuracy,* and content, satisfies criteria prescribed for such a *survey* by competent authority.

survey: topographic.—A *survey* which has for its major purpose the determination of the configuration (*relief*) of the surface of the earth (ground), and the location of natural and artificial objects thereon. Also the designation of an organization making such a *survey.*

A topographic survey is usually published as a *topographic map.*

survey: transit-and-stadia.—A *survey* in which *directions,* horizontal and vertical, are observed with a *transit* (engineer's), and distances are measured with a *transit* and *stadia.*

A transit-and-stadia survey is usually processed in the office, thus differing from a *survey* made with *alidade* and plane-table, where the *map* is made in the field as the observations are taken. An exception is found in the *topographic survey* of Baltimore, made in the 1890's, where *transit* and plane-table were used together in the field, and the *map* constructed as the observations were made.

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survey net.—1. Horizontal control survey net: arcs of *triangulation*, sometimes with lines of *traverse*, connected together to form a system of loops or circuits extending over an area. Variously spoken of as a triangulation net, traverse net, etc.

2. Vertical control survey net: lines of *spirit leveling* connected together to form a system of loops or circuits extending over an area. Also called a level net. See *control: national control survey nets.*

survey signal.—See under *signal.*

survey traverse.—See under *traverse.*

surveying.—The art of making a *survey.*

surveying: geodetic.—That branch of the art of *surveying* in which account is taken of the figure and size of the earth. Also called geodetic engineering.

In geodetic surveying, prescribed *precision* and *accuracy* of results are obtained through the use of special instruments and field methods, and formulas based on the geometry of a mathematical figure approximating the earth in form and size.

surveying: land.—The determination of boundaries and areas of tracts of land.

Land boundaries are usually defined by ownership, commencing with the earliest owners, and descending through successive ownerships and partitions. Land surveying includes the re-establishment of original boundaries, and the establishment of such new boundaries as may be required in the partition of the land. The term *"cadastral survey"* is sometimes used to designate a land survey, but in this country its use should be restricted to the surveys of the *public lands of the United States.*

surveying: plane.—A branch of the art of *surveying* in which the surface of the earth is considered a plane surface.

In plane surveying, curvature of the earth is neglected and computations are made using the formulas of plane geometry and plane trigonometry. In general, plane surveying is applied to *surveys* of land areas and boundaries (*land surveying*), where the areas are of limited extent or the required *accuracy* so low that *corrections* for the effect of curvature would be negligible as compared with the *errors* of observation. For small areas, precise results may be obtained with plane-surveying methods, but the *accuracy* and *precision* of such results will decrease as the area surveyed increases in size.

surveying: trilinear.—The determination of the position of a point of observation by measuring the *angles* at that point between lines to three points of known position. See under *resection.*

This determination involves the solution of the *three-point problem,* which is accomplished analytically by computation or graphically by the use of chorograph or *station pointer,* such as the *three-arm protractor.*

surveyor's compass.—See under *compass.*

surveys and maps: detailed.—*Surveys* and *maps* which take account of the smaller features and variations of features in the area surveyed.

A detailed *survey* implies a large-scale *map* of a small area, with increased *accuracy* and *precision* in both field and office work.

synodical (ordinary) month.—See under *month.*

systematic error.—See under *error.*

T

tachymeter, tacheometer, tachometer.—A surveying instrument designed for use in the rapid determination of distance, direction, and difference of *elevation* from a single observation, using a short base, which may be an integral part of the instrument.

There are several forms of instruments which might be called tachymeters. 1. An instrument in which the base line for distance determinations is an integral part of the instrument. It is to this type of instrument that the term "tachymeter" is usually applied. The so-called *range finders* with self-contained bases belong to this class, but are usually spoken of as *range finders,* and do not usually afford the means for the determination of elevation. 2. An instrument equipped with *stadia* wires or *gradienter,* the base for distance determination being a graduated rod held at the distant point.

tachymetry; tachometry.—A method of *surveying* for the rapid determination of distance, *direction,* and relative *elevation* of a point with respect to the instrument station, by a single *observation* on a rod or other object at the point.

The stadia method of *surveying* is the best example of tachymetry in this country, but the term tachymetry is little used here. Little used, too, are the associated terms given types of instruments used in this work, namely, *tachymeter* (or *tacheometer, tachometer*), and tacheographometer.

Talcott method, latitude determination.—See under *zenith-telescope method, latitude determination.*

tangency, point of.—See under *curve.*

tangent (surveying).—1. A straight line that touches a given curve at one and only one point, and does not intersect it.

2. That part of a *traverse* or *alignment* included between the *point of tangency* of one curve and the *point of curvature* of the next curve.

3. In the *surveys of the public lands of the United States,* a *great circle line* tangent to a *parallel* of *latitude* at a *township corner.*

tangent distance.—The distance from the *point of intersection* (vertex) of a curve to its *point of tangency* or *point of curvature.*

tangent method (United States public-land surveys).*—A method of determination of the *parallel* of *latitude* for the survey of a *base line* or *standard parallel* by *offsets* from a *great circle line* initiated at an established *township corner* and tangent to the *base line* or *standard parallel* at that corner.

The tangent *great circle* is projected at an angle of 90° from the *meridian* at the *township corner* from which initiated, and proper *offsets* are measured north from the tangent to the *parallel* upon which the *corners* are established.

tangent plane.—A plane that touches a curved surface at one and only one point.

In *geodetic* work, a plane tangent to the *spheroid* at any point is perpendicular to the *normal* at that point. Tangent planes have been used in computing *map projections* for small areas (local systems of *map projections*).

tape: alignment correction.—A *correction* applied to the measured length of a line to allow for the tape not being held exactly in a *vertical plane* containing the line.

Though the *vertical planes* at the two ends of a line which contain the *direction* of the line at those points are not coincident, they are practically so for all *surveying* purposes, and any method of aligning a base between its end points will serve in determining an alignment correction.

tape: base.—See under *base tape.*

tape: grade correction.—A *correction* applied to a distance measured on a slope to reduce it to a horizontal distance between the vertical lines through its end points. Also called slope correction, correction for inclination of tape.

As the vertical lines through the end points of a line are not parallel, the reduction should be such that the length at the average *elevation* will be obtained. In practice this is accomplished by considering each tape length a separate line, and reducing it individually. In *base line* measures, the difference in *elevation* of the ends of the tape are used in computing the grade correction, rather than the *grade* or inclination of the line expressed in angular form. In effect, this treatment applies the grade correction to the nominal length of the tape in determining its effective length in measuring a distance.

tape: invar.—See under *base tape.*

tape: length correction.—The difference between the nominal length of a tape and its effective length under conditions of *standardization.*

The standard length of a tape is usually expressed by a number of whole units (the nominal length) plus or minus a small distance which is the length correction defined above. Provision is also made for determining any changes of length caused by thermal expansion (or contraction) of the tape.

tape: sag correction (catenary correction).—The difference between the effective length of a tape (or part of a tape) when supported continuously throughout its length and when supported at a limited number of independent points.

Base tapes are usually used with 3 or 5 points of support, and hang in curves (catenaries) between adjacent supports. Correction for sag is not required when the method of support in use is the same as was used in the *standardization* of the tape. A *base tape* may also be used supported throughout or with 4 points of support, as on a railway rail.

tape: temperature correction.—The quantity applied to the nominal length of a tape to allow for a change in its effective length due to its being used at a temperature other than that for which its *standard* length is given.

Temperature correction is applied when the temperature of the tape in use is different from the temperature given in a statement of its standard length.

tape: tension correction.—The *correction* applied to the nominal length of a tape to allow for a change in effective length due to its being used at a tension other than that for which its standard length is known.

A tension correction is not required when the tape is used in the field at the tension of *standardization.*

tape corrections.—*Corrections* applied to a distance measured with a tape to eliminate *errors* due to the physical condition of the tape, and to the manner in which it is used.

Tape corrections which are functions of the physical condition of the tape are *length correction, temperature correction,* and *tension correction.* A *correction* which may be required because of the method of using the tape is the *catenary correction* (*correction for sag*). Closely associated with these are *corrections* which depend upon the position of the line on the ground, as actually measured. These include *grade correction,* and *alignment correction,* which are sometimes treated as *corrections* to the tape itself as used. Reduction to a *datum* (such as *mean sea level*) is not considered as a tape correction.

tape stretcher.—A mechanical device which facilitates holding a tape at a prescribed tension and in a prescribed position.

taping.—The operation of measuring a distance on the earth, using a tape or ribbon of metal or other material. See *chaining.*

The term taping is used for all *surveys* except those of the *public lands of the United States;* for those, due to historical and legal reasons, the term *chaining,* and its related term *chainmen,* are preferred. The men who mark the two ends in taping are termed contact men.

target rod.—See under *leveling rod (general).*

telescope.—An optical intrument consisting essentially of two systems of lenses: an objective or object glass which brings rays of light from a distant object to a *focus* within the telescope tube; and an eyepiece or ocular with which the image of the distant object formed by the objective is magnified and examined.

By means of a *reticle* placed in the principal *focus* of a telescope, definite lines of sight are established, and the telescope thereby made into a *precision* instrument for *surveying* and astronomic work. The magnifying power of a telescope depends upon the ratio of the *focal lengths* of the objective and eyepiece lenses.

telescope: achromatic.—See under *achromatic telescope.*

temperature correction (leveling).—See under *correction.*

temperature correction, pendulum.—See under *pendulum.*

temperature correction, tape.—See under *tape.*

template (templet).—A gage or pattern to guide certain work that is to be done.

A template is often a thin sheet of transparent material upon which suitable guide lines are drawn. Examples: the ordinary *protractor* or, in photographic mapping, a transparent celluloid overlay made over a photograph, showing the center and all radial lines from the center through images of control points, as well as (azimuth) lines connecting the center with images of points which show on the photograph and are themselves the centers of other photographs. In obtaining *elevation* readings from *maps* in connection with *topographic* and *isostatic* reductions, templates of celluloid are used. The templates used in connection with *deflection of the vertical* studies have circles and radial lines drawn upon them, so proportioned with reference to *scale of map* and *azimuth* that land *elevations* and ocean depths within each compartment formed by adjacent arcs and radii can be easily averaged and the effect of the mass therein upon a plumb line at the station (center of circles), under various hypotheses, can be computed. The templates used in connection with *gravity* studies are similar to those described above, except that no account is taken of *azimuth,* all compartments bounded by a given pair of circles being of the same size and shape. A given template can be used only on maps of the *scale* and *projection* for which it is constructed. Devised by J. F. Hayford in connection with studies for the figure of the earth and *isostasy,* these templates are known as the Hayford deflection templates and the Hayford gravity templates.

Temple Act.—An Act of the Congress of the United States to adopt a program for the completion of the *Topographic Map of the United States.*

Known as H. R. 4522, 68th Congress, 1st Session, the bill which later (1925) became the Temple Act, was introduced in 1924 by Dr. Henry W. Temple, a

Representative from Pennsylvania. No appropriations were made for carrying out its provisions.

temporary bench mark.—See under *bench mark.*

tension correction, tape.—See under *tape.*

terrain correction (geländereduktion).—The correction for the effect, upon the acceleration of gravity at a point, of the departure of the actual topography from an assumed plateau at the elevation of the point.

The correction has the same sign whether the topography lies above or below the plateau.

terrestrial equator.—See under *equator: astronomic.*

terrestrial meridian.—See under *meridian.*

terrestrial refraction.—See under *refraction.*

tertiary triangulation.—See under *triangulation.*

thalweg.—The line following the lowest part of a valley, whether under water or not.

The intricacy of detail in ordinary *relief* often makes difficult a practical location of a thalweg; in a survey of a political *boundary line* this difficulty may assume considerable weight. A thalweg may also be defined as the line down the center of the main channel of a stream; or as the line of greatest slope, cutting all *contours* at right *angles.*

theodolite.—A *precision surveying* instrument consisting of an *alidade* with *telescope,* mounted on an accurately graduated circle, equipped with necessary levels, and reading devices. Sometimes, the *alidade* carries a graduated *vertical circle.*

There are two general classes of theodolites: *direction theodolites,* often referred to as *direction instruments,* and *repeating theodolites.*

theodolite: astronomical.—See under *alt-azimuth instrument.*

theodolite: direction instrument.—A *theodolite* in which the graduated horizontal circle remains fixed during a series of observations, the *telescope* being pointed on a number of signals or objects in succession, and the *direction* of each read on the circle, usually by means of *micrometer microscopes.*

In measuring *horizontal angles* with a direction instrument, *angles* are not repeated (accumulated) on the circle, but *precision* and *accuracy* are obtained by having the circle of high quality, by using *precision* methods of reading the circle, and by shifting the circle between sets, so that each *direction* is measured on a number of different parts of the circle. Direction instruments are used almost exclusively in *first-* and *second-order triangulation.*

theodolite: Parkhurst.—A *direction theodolite* designed by and named for D. L. Parkhurst, and used on *first-* and *second-order control surveys.*

The distinctive features of the Parkhurst theodolite are its non-binding center, ball-bearing clamp ring, illumination through the central axis, discontinuous conical bearings, illuminated glass micrometer drums, and improved designs for tangent-screw assembly, clamp-block assembly, and micrometer mountings.

theodolite: photo. —An instrument used in terrestrial photogrammetry, and consisting of a combination of *theodolite* and camera, using the same tripod.

In some models, the theodolite and camera can be used separately; in other models, the two are combined in a single instrument.

theodolite: repeating.—A *theodolite* so designed that successive measures of an *angle* may be accumulated on the graduated circle, and a final reading of the circle made which represents the sum of the repetitions.

The observed value of the *angle* is obtained by dividing the total *arc* passed through in making the series of observations by the number of times the *angle* has been observed. The total *arc* passed through may include several complete circuits of the circle, which must be added to the circle reading before making the division. The repeating *theodolite* is also called a repeating instrument. Theoretically, it is an instrument of great *precision,* but in its mechanical operation it does not give as satisfactory results as the *direction instrument.*

theodolite: Wild.—A make of *theodolite* which has the horizontal and *vertical circles* graduated on glass, and read by an arrangement of prisms which brings the images of opposite portions of either of the circles into the field of view of a reading microscope mounted alongside the *telescope.* By mechanical means the graduation marks in the two images are brought into coincidence, and the circle read by means of an auxiliary seconds scale.

The seconds scale is read to single seconds or to a decimal part of a second without moving from the eye end of the *telescope.* A single reading thus obtained is the mean of two readings of diametrically opposite points on the graduated circle and is therefore free from *errors* due to *eccentricity of circle.* The Wild theodolite is well adapted for use in *triangulation* of any order.

theoretical (or external) error.—See under *error.*

thermometric leveling.—See under *leveling.*

third-order leveling.—See under *leveling.*

third-order traverse.—See under *traverse.*

third-order triangulation.—See under *triangulation.*

third-order work.—See under *traverse; triangulation;* and *leveling.*

thread of river, middle.—The line equidistant between the *low-water* lines on the two sides of a river, extending from headland to headland without considering arms, inlets, creeks, and affluents as parts of the river.

thread of stream.—The line equidistant from the edge of the water on the two sides of the stream at the ordinary stage of the water. See under *thread of river, middle.*

three-arm protractor.—See under *protractor.*

three-point problem.—The determination of the horizontal *position* of a point of observation from data comprising two observed *horizontal angles* between three objects of known *position.*

The problem is solved graphically by means of a *three-arm protractor,* and analytically by trigonometrical calculation. See *resection.* In plane-table surveying it is solved graphically by trial and error.

tidal bench mark.—See under *bench mark.*

tidal datum.—See under *datum.*

tideland.—Land along tidal waters that is below *mean high water* and above *mean low water,* that is, the *shore.*

tie.—A survey connection from a point of known *position* to a point whose *position* is desired.

A tie is made to determine the *position* of a supplementary point whose *position* is desired for mapping or reference purposes, or to close a *survey* on a previously determined point. To "tie in" is to make such a connection. The point to which the connection is made is called a "tie point."

tie point.—See under *tie.*

tier (United States public-land surveys).*—Any series of contiguous *townships* situated east and west of each other; also *sections* similarly situated within a *township.*

time.—The measurable aspect of duration.

Time makes use of scales based upon the happening of periodic events, as follows:
1. The *day,* depending upon the *rotation* of the earth.
2. The *month,* depending upon the *revolution* of the moon around the earth.
3. The *year,* depending upon the *revolution* of the earth around the sun.

When one says it is a certain time, one expresses a length on a duration scale measured from an index on that scale.

For example: 4 p. m. local *mean solar time* means that 4 mean solar hours have elapsed since the *mean sun* was on the *meridian* of the observer.

time: apparent.—See under *time: apparent solar time.*

time: apparent solar.—*Time* measured by the apparent diurnal motion of the (true) sun. Also termed true solar time, and often, apparent time.

At any given instant, the apparent solar time is the *hour angle* of the (true) sun. In civil life, apparent solar time is counted from the two branches of the *meridian* through 12 hours; the hours from the lower branch are marked "A. M." (ante meridian); those from the upper branch, "P. M." (post meridian). In astronomic work, before 1925, apparent solar time was counted from the upper branch of the *meridian* through 24 hours (see *astronomical time*); since 1925, the count has been from the lower branch, and the *civil day* has taken the place of the *astronomical day* in astronomical work. Naming the *meridian* of reference is essential to the complete identification of the *time.* For example, 75th meridian apparent solar time; Greenwich apparent solar time; local apparent solar time (for the *meridian* of the observer). Because of variations in the apparent motion of the sun, a clock or watch cannot be adjusted to show apparent solar time. Apparent solar time is *time* determined by observations on the (true) sun. It is the *time* shown by a sun dial. See *time: equation of time.*

time: astronomical.—*Solar time* in a *day* (*astronomical day*) that begins at noon.

Astronomical time may be either *apparent solar time* or *mean solar time.* It is counted from noon in a single series of 24 hours. Astronomical time appears in the American Ephemeris and Nautical Almanac prior to 1925; but in the volumes for 1925 and later, *civil time* is used instead.

time: civil.—*Solar time* in a day (*civil day*) that begins at midnight.

Civil time may be either *apparent solar time* or *mean solar time;* it may be counted in two series of 12 hours each, beginning at midnight, marked "A. M." (ante meridian), and at noon, marked "P. M." (post meridian), or in a single series of 24 hours beginning at midnight.

time: daylight-saving.—A substitute for *standard time,* exactly 1 hour fast on that *time.*

Clocks showing *standard time* are changed to daylight-saving time by moving the hands ahead exactly 1 hour. Until 1942, it was not adopted by the railroads, nor generally throughout the country; and where adopted, it was for use only during the summer months. In 1942, it was adopted by Congress for general use, and unofficially given the name of *war time.* The time in a given time belt is identified by the particular designation of the belt: Eastern Daylight Saving Time; Central Daylight Saving Time; etc.

time: equation of.—The difference in *hour angle* between *apparent solar time* and *mean solar time.*

The sun is sometimes before and sometimes behind the *mean sun* by an amount that ranges from 0 to about 16 minutes of *time.* As the equation of time may be expressed as a *correction* to either *apparent solar time* or to *mean solar time,* its sign must be carefully observed.

Time: Greenwich Civil.—*Mean solar time* for the *Greenwich Meridian,* counted from midnight. Also called *Universal Time* (U. T.).

Greenwich Civil Time (G. C. T.) is a reference used in the American Ephemeris and Nautical Almanac for 1925 and thereafter. It is counted from midnight through 24 hours.

Time: Greenwich Sidereal.—The *sidereal time* for the *Greenwich Meridian.*

time: local apparent.—The *apparent solar time* for the *meridian* of the observer.

time: local mean.—The *mean solar time* for the *meridian* of the observer.

time: local sidereal.—The *sidereal time* for the *meridian* of the observer.

time: mean solar.—*Time* measured by the diurnal motion of a fictitious body, called the mean sun, which is supposed to move uniformly in the *celestial equator,* completing the circuit in one *tropical year.* Often termed simply mean time.

The mean sun may be considered as moving in the *celestial equator* and having a *right ascension* equal to the mean *celestial longitude* of the true sun.

At any given instant, mean solar time is the *hour angle* of the mean sun. In civil life, mean solar time is counted from the two branches of the *meridian* through 12 hours; the hours from the lower branch are marked "A. M." (ante meridian); those from the upper branch, "P. M." (post meridian). In astronomical work, before 1925, mean solar time was counted from the upper branch of the *meridian* through 24 hours (see *astronomical time*); since 1925, the count has been from the lower branch. Naming the *meridian* of reference is essential to the complete identification of the *time.* For example, 75th meridian mean solar time; Greenwich mean solar time; local mean solar time for the *meridian* of the observer. By using the same reference *meridian* over a belt or zone of the earth, watches and clocks are adjusted to show the same mean solar time throughout the area (see *standard time*). The *Greenwich Meridian* is the reference for a world-wide standard of mean solar time, called *Greenwich Civil Time* or *Universal Time.* The mean sun being a fictitious body, mean solar time cannot be determined directly by observation. See *time: equation of time.*

time: sidereal.—*Time* measured by the apparent diurnal rotation of the (true) *vernal equinox.*

At any instant, sidereal time is the *hour angle* of the *vernal equinox.* It is counted from 0 hours, when the *vernal equinox* is on the *meridian,* through 24 hours. Naming the *meridian* of reference is essential to its complete identification. For example, 75th meridian sidereal time; *Greenwich sidereal time; local sidereal time* for the *meridian* of the observer.

On account of small differences between the positions of the true and mean *equinoxes,* sidereal time, like the *sidereal day,* is subject to slight irregularities. These irregularities are absent from (uniform) sidereal time, which is measured by the motion of the mean equinox, and is used in rating clocks of the highest *precision*.

time: solar.—See under *time: apparent solar time; mean solar time.*

time: standard.—*Mean solar time* for a selected *meridian* adopted for use throughout a belt (zone).

In the continental United States, the *meridians* of reference for standard time are 15° (1 hour) apart, and multiples of 15° from the initial *meridian, Greenwich Meridian.* The standard time for each belt is designated by the number of its *meridian,* and also by some name of *geographic* significance: 75th meridian or Eastern Standard Time; 90th meridian or Central Standard Time; 105th meridian or Mountain Standard Time; and 120th meridian or Pacific Standard Time. The standard time meridians for Alaska are 150° and 165° west *longitude;* for Hawaii, 150° west *longitude;* for the Philippine Islands, 120° east *longitude.* Standard time was established in 1883 to correlate train schedules of various railroads over the same areas. The standard time belts were planned to be roughly symmetrical with respect to the *meridians* of reference, and to extend 7½° to either side thereof. Practical considerations, such as the need of time correlation of cities outside the original boundaries of a time belt with cities within the belt, have caused a gradual shifting of those boundaries until some of them now exhibit large irregularities. See *time: daylight-saving time; war time.*

time: true solar.—See under *time: apparent solar time.*

Time: Universal (U. T.).—The same as *Greenwich Civil Time (G. C. T.).*

The first use of Universal Time as a reference in the American Ephemeris and Nautical Almanac is in the volume for the year 1939.

time: war.—*Daylight-saving time* as prescribed in 1942 by Act of Congress.

The use of war time throughout the country was inaugurated on February 9, 1942, clocks being set ahead 1 hour at 2 A. M. standard time on that date (Public Law 403, 77th Congress). Its use by State and local agencies was not mandatory, except where State legislation so directed. The time in any given *time* belt was identified by the particular designation of that belt: Eastern War Time; Central War Time; etc. The use of war time was discontinued on September 30, 1945, at 2 A. M.

toise.—A unit of length used in early *geodetic surveys* and equal to about 6.4 English feet.

The Toise of Peru was an iron *standard* used in measuring the *base lines* which controlled the lengths of the Peruvian Arc (of *triangulation*), executed in 1736–1743, in connection with a determination of the figure and size of the earth. The Toise of Peru became the legal *standard* of length in France, and from it was derived the *French legal meter,* as follows: the toise was divided into 6 pieds (feet); each pied was divided into 12 pouces (inches); each pouce was divided into 12 lignes (lines); and one *French legal meter* was equal to 443.296 lignes exactly at a temperature of 13° Réaumur. The Peruvian Arc does not lie in modern Peru, but in Ecuador, which was included in the old Spanish presidency of Peru.

Toise of Peru.—See under *toise.*

tolerance (general).—The permissible deviation from a *standard.*

In *surveying* operations the prescribed limiting *probable error* may be regarded as an expression of tolerance, though the term tolerance is seldom used in connection with *survey* results. Its use may well be confined to stating the permissible deviation from exactness in the fitting together of the component parts of physical apparatus: for example, the *pivot inequality* of an *astronomical transit.*

topographic deflection.—That portion of the *deflection of the plumb line* which is due to the gravitational pull exerted by topographic masses.

Topographic deflection is not the same as *deflection of the plumb line* or *station error,* but is the theoretical effect produced by the resultant gravitational pull of the unevenly distributed topographic masses around the station, no allowance being made for *isostatic compensation.*

topographic feature.*—A prominent or conspicuous *topographic form* or salient part thereof.

topographic form.*—A *land form* considered without regard to origin, cause, or history.

topographic map.—See under *map.*

Topographic Map of the United States.—See under *map.*

topography (or relief).*—The features of the actual surface of the earth, considered collectively as to form.

A single feature, such as a mountain or valley, is called a *topographic feature.*

torsion balance.—A device for measuring very small forces of attraction due to *gravitation,* magnetism, etc., and consisting of a bar suspended horizontally by an elastic filament, one end of the bar being subjected to the influence of the attracting force in a much greater degree than the other end. The attracting force is balanced and its comparative strength measured by the torsional reaction of the filament.

In geophysical prospecting, a form of torsion balance is employed in determining the gradient of *gravity,* the *horizontal direction* in which the intensity of *gravity* increases or decreases most rapidly, so that in a *survey* of a large area, any existing large mass of abnormal density may be discovered. For example, the oil fields of the Gulf Coast are associated with salt domes—plugs of salt of such size and density that they are easily discovered and located by geophysical methods. Among the instruments used in making such discoveries is the torsion balance.

township (United States public-land surveys).*—The unit of survey of the *public lands* of the United States, normally a quadrangle approximately 6 miles on a side with boundaries conforming to *meridians* and *parallels,* located with reference to the *initial point* of a *principal meridian* and *base line.*

Townships are numbered consecutively north and south from a *base line;* thus "township 14 north" indicates a township in the 14th *tier* north of a *base line.* The word township is used in conjunction with the appropriate *range* to indicate the *coordinates* of a particular township with reference to the initial point; thus "township 14 north, range 3 east" indicates the particular township which is the 14th township north of the *base line* and the 3rd township east of the *principal meridian* controlling the surveys in that area. The plural form, townships or tps., is used whenever more than one unit is indicated; "townships 14 north, ranges 3, 4, and 5 east"; "townships 14 and 15 north, range 3 east."

township: fractional (United States public-land surveys).*—A *township* containing appreciably less than 36 normal *sections,* usually due to invasion by a segregated body of water, or by other land which cannot properly be surveyed as part of that *township.*

Townships may be rendered fractional also in closing the public-land surveys on State boundaries, or other limiting lines.

township line (United States public-land surveys).*—An exterior boundary of a *township* extending in an east-west direction.

track level.—See under *track sector.*

track sector.—An instrument composed of a half-circle *protractor* with a single movable arm which carries a *spirit level,* and is so constructed that when the *protractor* base is parallel with a railway rail and the *spirit level* bubble is in the center of its tube, the movable arm will register the slope (angle of inclination) of the rail. Also called track level.

The track sector was designed and used for determining the slope of the tape when used in *traverse* measures along a railway. Not proving satisfactory, its use was abandoned.

Transcontinental Triangulation datum.—See under *datum.*

transit.—1. The apparent passage of a star or other celestial body across a defined line of the celestial *sphere,* as a *meridian, prime vertical,* or *almucantar.* The apparent passage of a star or other celestial body across a line in the *reticle* of a *telescope,* or some *line of sight.* The apparent passage of a smaller celestial body across the disk of a larger celestial body.

2. A surveying instrument composed of a horizontal circle graduated in circular measure and an *alidade* with a *telescope* which can be reversed in its supports without being lifted therefrom. Also, the act of making such reversal.

3. An astronomical instrument having a *telescope* which can be so adjusted in position that the *line of sight* may be made to define a *vertical circle.*

1. When no line is specified, a transit across the *meridian* is usually intended. The transit of a star across the *meridian* occurs at the moment of its *culmination,* and the two terms are sometimes used as having identical meanings; such usage is not correct, even where the instrument is in perfect adjustment. At the poles, a star may have no *culmination,* but it will transit the *meridians.* The transit of a small celestial body across a larger one is exemplified by the transit of the planet Mercury across the disk of the Sun, or of a satellite of Jupiter across the disk of that planet. See *eclipse, occultation.*

2. A *theodolite* having a *telescope* that can be transited in its supports is a transit, and is sometimes termed a transit theodolite.

3. A transit used in astronomical work is usually called either an astronomical transit or a transit instrument.

transit: astronomical.—See under *transit,* 3.

transit: Bamberg.—See under *transit: broken-telescope transit.*

transit: broken-telescope.—An *astronomical transit* having its *telescope* so shaped that a ray of light entering the objective is reflected at right angles by a prism placed within the *telescope,* the reflected ray passing to the eyepiece which is in the *horizontal axis* of the *telescope* and outside its supporting wyes.

One make of broken-telescope transit, called the Bamberg broken-telescope transit or the Bamberg instrument, is described in two Special Publications of the U. S. Coast and Geodetic Survey: No. 35, Determination of the Difference in Longitude Between Each Two of the Stations Washington, Cambridge, and Far Rockaway, by Fremont Morse and O. B. French, 1916; and No. 109, Wireless Longitude, by George D. Cowie and E. A. Eckhardt, 1924. The term "bent transit" has also been applied to this instrument. The design of this instrument permits its use in the determination of *latitude* by the *zenith-telescope method.* It is given considerable weight without producing undesirable flexure. This and the unusually long distance between the supporting wyes make for stability. The *striding level* used with straight-telescope instruments is replaced with a *hanging level.* The position of the eyepiece being independent of the *altitude* of the object observed promotes convenience in observing. This instrument is used in first-order determinations of *astronomic longitude, astronomic latitude,* and recently has been used in first-order determinations of *astronomic azimuth* at stations in high *latitudes.* See *azimuth: micrometer method, determination of astronomic azimuth.*

transit: solar.—See under *solar transit.*

transit-and-stadia survey.—See under *survey.*

transit instrument.—See under *transit, 3.*

transit micrometer.—See under *micrometer.*

transit micrometer, contact correction.—See under *contact correction.*

transit rule: balancing survey.—See under *balancing a survey.*

transit traverse.—See under *traverse.*

transition curve.—See under *curve: spiral curve.*

Transportation Map of the United States.—See under *map.*

transverse Mercator grid.—An informal designation for a *State coordinate system* based on a *transverse Mercator map projection.*

transverse Mercator map projection.—See under *map projection.*

transverse polyconic map projection.—See under *map projection.*

traverse.—See under *traverse: survey traverse.*

traverse: astronomical.—A *survey traverse* in which the *geographic positions* of the stations are obtained from astronomic observations, and lengths and *azimuths* of lines are obtained by computation.

traverse: closed.—A *survey traverse* which starts and ends upon the same station, or upon stations whose *relative positions* have been determined by other *surveys.*

traverse: first-order.—A *survey traverse* which by itself forms a closed loop or which extends between *adjusted positions* of other *first-order control surveys,* and has a *closing error* in *position* not greater than 1 part in 25,000 of its length. The criteria prescribed for attaining the required *accuracy* and *precision* are as follows: The *probable error* of any main-scheme *angle* shall not exceed $\pm 1.5''$; the number of *angle* stations between *astronomic-azimuth* stations to be 10 to 15 in number; the *discrepancy* per main-scheme *angle* station between *astronomic azimuths* not to exceed $1.0''$; the *probable error* of the *astronomic azimuths* not to exceed $\pm 0.5''$.

Formerly known as *precise traverse,* the present designation of first-order traverse was recommended by the Federal Board of Surveys and Maps in May 1925. Lacking the geometrical checks obtainable in *triangulation,* first-order traverse, though formerly used in the fundamental *control survey* of the country, is no longer so used.

traverse: fourth-order.—A *survey traverse* of an *accuracy* less than *third-order traverse.*

In fourth-order traverse, *angles* are observed with a *transit* or *sextant* or are determined graphically, and distances are measured with tape, *stadia,* or wheel.

traverse: geographical exploration.—A route followed across some part of the earth, approximate *positions* along which are determined by *surveying* or navigational methods.

traverse: open.—A *survey traverse* which starts from a station of known or adopted *position,* but does not end upon such a station.

traverse: random.—A *survey traverse* run from one station to another survey station which cannot be seen from the first station, in order to determine their *relative positions.* See *random line.*

traverse: second-order.—A *survey traverse* which by itself forms a closed loop or which extends between adjusted stations of *first-* or *second-order control surveys,* and has a *closing error* in position of between 1 part in 10,000 and 1 part in 25,000 of its length. The following additional criteria are prescribed for the attainment of the required *accuracy* and *precision: probable error* of main-scheme *angles* not to exceed ±3.0″; number of *angle* stations between *astronomic-azimuth* stations, 15 to 25; *discrepancy* per main-scheme *angle* station between *astronomic azimuths,* not to exceed 2.0″; *probable error* of *astronomic azimuths,* not to exceed ±2.0″.

The present designation, second-order traverse, was recommended by the Federal Board of Surveys and Maps in May 1925.

traverse: survey.—A sequence of lengths and *directions* of lines between points on the earth, obtained by or from field measurements, and used in determining *positions* of the points.

A survey traverse may determine the *relative positions* of the points which it connects in series, and if tied to *control stations* on an adopted *datum,* the *positions* may be referred to that *datum.* Survey traverses are classified and identified in a variety of ways: according to methods employed, as, *astronomical traverse;* quality of results, as, *first-order traverse;* purpose served, as, *geographical exploration traverse;* according to form, as, *closed traverse,* etc.

traverse: third-order.—A *survey traverse* which by itself forms a closed loop or which extends between adjusted stations of other *control surveys,* and has a *closing error* in *position* of between 1 part in 5,000 and 1 part in 10,000 of its length. The following additional criteria are prescribed for attaining the required *accuracy* and *precision: probable error* of main-scheme *angles* not to exceed ±6.0″; number of *angle* stations between *astronomic-azimuth* stations, 20 to 35; *discrepancy* per main-scheme *angle* station between *astronomic azimuths,* not to exceed 5.0″; *probable error* of *astronomic azimuths,* not to exceed ±5.0″.

The present designation, third-order traverse, was recommended by the Federal Board of Surveys and Maps in May 1925.

traverse: transit.—A *survey traverse* in which the *angles* are measured with an engineer's *transit* or *theodolite* and the lengths with a metal tape.

A transit traverse is usually executed for the control of local surveys and is of *second-* or *third-order* quality.

traverse net.—See under *survey net.*

traverse tables.—Mathematical tables listing the lengths of the sides opposite the oblique *angles* for each of a series of right-angle plane triangles, as functions of the length and *azimuth* (or *bearing*) of the hypotenuse.

Traverse tables are used in computing *latitudes* and *departures* in surveying and of *courses* in navigation. One argument of such a table is the *angle* which the line or *course* makes with the *meridian* (its *azimuth* or *bearing*), and the other argument is a distance. In tables used in *land surveying,* the distance argument is usually a series of integers, from 1 to 9, with which lines of greater length may be composed. In navigation, the distance argument may run to several hundred miles.

triangulation.—A method of *surveying* in which the stations are points on the ground at the vertices of a chain or network of triangles, whose *angles* are observed instrumentally and whose sides are derived by computation from selected triangle sides called *base lines,* the lengths of which are obtained from direct measurements on the ground.

Triangulation permits the selection of sites for stations and *base lines* favorable for use both from topographic and geometric considerations (see *strength of figure*); it is well adapted to the use of *precision* instruments and methods in all its operations, and susceptible of great *accuracy* and *precision* in its results. Triangulation is generally used where the area surveyed is large and requires the use of *geodetic methods.* Triangulation may be considered as including not only the actual operations of observing *angles* and measuring *base lines,* and their mathematical processing, but also the *reconnaissance* which precedes those operations, and the astronomic observations which are required in the establishment of a *geodetic datum* and in the control of the triangulation.

triangulation: arc.—A system of *triangulation* of limited width designed to progress in a single general direction.

Arc triangulation is executed for the purpose of connecting independent and widely separated *surveys, coordinating,* and *correlating* local surveys along the arc, furnishing data for the determination of a *geodetic datum,* providing a network of control points for a country-wide *survey,* etc. See *area triangulation.*

triangulation: area.—A system of *triangulation* designed to progress in every direction.

Area triangulation is executed to provide survey control points over an area, as of the city or county; or for filling in the areas between *arcs* of *triangulation* which form a network extending over a county or State. See *arc triangulation.*

triangulation: first-order.—*Triangulation* conforming to the following criteria: the average *error of closure* of the main-scheme triangles shall not exceed 1″; the maximum *error of closure* of the main-scheme triangles shall not exceed 3″; the *error of closure* in length on a measured *base line* or on a line of adjusted first-order triangulation shall not exceed 1/25,000 of the length of the line after the *angle* and *side* equations have been satisfied in the *adjustment.*

First-order triangulation was at one time known as *primary triangulation;* this was changed in 1921 to *precise triangulation;* and in May 1925 the present designation was recommended for adoption by the Federal Board of Surveys and Maps. The report of that Board recommended that the four grades of horizontal and vertical control ordinarily used be designated as first order, second order, third order, and fourth order, respectively, the first-named being the most *accurate.*

triangulation: flare.—A method of *triangulation* in which simultaneous observations are made on parachute flares. This method is used for extending triangulation over lines too long to be observed by ordinary methods.

triangulation: precise.—The designation which, from 1921 until the present terminology was adopted in 1925, was applied to what is now called *first-order triangulation.*

triangulation: primary.—The designation which, prior to 1921, was given to what is now called *first-order triangulation;* and thereafter and until the present terminology was adopted in 1925, was applied to what is now called *second-order triangulation.*

triangulation: secondary.—The designation which, prior to 1921, was given to what is now called *second-order triangulation;* and thereafter and until the present terminology was adopted in 1925, was applied to what is now called *third-order triangulation.*

triangulation: second-order.—*Triangulation* which does not attain the quality of *first-order triangulation* but does conform to the following criteria: the average *error of closure* of the main-scheme triangles shall not exceed 3″; the maximum *error of closure* of the main-scheme triangles shall not exceed 5″; the *error of closure* in length on a measured base line or on a line of adjusted first- or second-order triangulation shall not exceed 1/10,000 of the length of the line after the *angle* and *side equations* have been satisfied in the *adjustment.*

Second-order triangulation was at one time known as *secondary triangulation;* later (1921) the name was changed to *primary triangulation;* and in May 1925 the present designation was recommended by the Federal Board of Surveys and Maps.

triangulation: ship-shore.—A method of extending *triangulation* along a coast by making simultaneous observations from three or more shore stations on a target mounted on an anchored ship.

This method is used only when it is impractical to establish a chain of triangles or quadrilaterals.

triangulation: tertiary.—The designation which, prior to 1921, was given to what is now called *third-order triangulation.*

triangulation: third-order.—*Triangulation* which does not attain the quality of *second-order triangulation,* but does conform to the following criteria: the average *error of closure* of the main-scheme triangles shall not exceed 5″; the maximum *error of closure* of the main-scheme triangles shall not exceed 10″; and the closure in length on a measured *base line* or on a line of adjusted *triangulation* shall not exceed 1/5,000 of the length of the line after the *angle* and *side equations* have been satisfied in the *adjustment.*

Third-order triangulation was at one time known as *tertiary triangulation;* later (1921) the name was changed to *secondary triangulation;* and in May 1925 the present designation was recommended by the Federal Board of Surveys and Maps.

triangulation arc.—A system of *triangulation* forming a band or belt on the surface of the earth. Or the corresponding system of *positions,* lines, and *angles* on the surface of the *spheroid.*

The axis of a triangulation arc may *approximate* in position an *arc* on the spheroid, following a *meridian* of *longitude,* a *parallel* of *latitude,* or an oblique *arc;* it may follow a natural feature as a river; or it may follow an artificial feature, as a civil boundary. It is usually given an identifying name corresponding to its general or particular location, or having other geographic significance: as Ninety-eighth Meridian Arc, Mississippi River Arc, etc.

triangulation net.—See under *survey net.*

triangulation signal.—See under *signal.*

triangulation station.—A point on the earth whose *position* is determined by *triangulation.*

triangulation tower.—A *triangulation signal* consisting of two separate structures, independent of one another; an inner structure which supports the *theodolite* and sometimes the target or signal lamps, and an outer structure which supports the observer and his assistants and sometimes the target or signal lamps.

Triangulation towers are used to elevate the *line of sight* above trees, *topographic features,* and other obstacles that might interfere with the observing. Before 1927, towers of wood were used, the inner structure being a tripod and the outer structure a four-leg scaffold. In 1927, the *Bilby steel tower* was put into use. Triangulation towers more than 100 feet in height are not unusual.

triaxial ellipsoid.—See under *ellipsoid.*

tribrach.—The three-arm base of a surveying instrument which carries the foot-screws used in leveling the instrument.

Many surveying instruments have a four-screw base or quadribrach. Such an instrument is not suitable for third- or higher-order horizontal control, for the leveling process may introduce strains in the base of the instrument which will tend to change the instrument in *azimuth* while the observations are being made.

trigonometric leveling.—See under *leveling.*

trilateration.—A method of extending horizontal control where the sides of triangles are measured rather than the angles as in triangulation.

trilinear surveying.—See under *surveying.*

trivet.—A device for use in place of a tripod in mounting a *transit* or *level.* It is essentially a tripod head with three very short legs cast as a single piece of metal.

It is used for placing a *transit* or *level* in a position where a regular tripod could not be conveniently used, or where greater stability is desired. When used for a *theodolite,* a trivet may include the foot-plate with V-shaped grooves cut in suitable arms to receive the feet of the leveling screws.

Tropic of Cancer.—Astronomy. The *parallel of declination* passing through the *summer solstice.* Geography. The *geographic parallel* whose *latitude* corresponds to the *declination* of the *summer solstice.*

The *obliquity of the ecliptic* is steadily changing so that the *summer solstice* is not a point of fixed *declination.* When the Tropic of Cancer is to be shown on a terrestrial *map,* it is desirable that it be treated as a line of fixed *latitude,* and for this purpose it is here proposed that the value 23°27′ north *latitude* be adopted and used.

While, in popular usage, the term "tropics" is sometimes applied to the belt of the earth's surface bounded by the Tropic of Cancer and the *Tropic of Capricorn,* in technical language, the term designates the lines themselves, the included area being known as the "Torrid Zone." "Tropics" also has a climatic connotation.

Tropic of Capricorn.—Astronomy. The *parallel of declination* passing through the *winter solstice.* Geography. The *geographic parallel* whose *latitude* corresponds to the *declination* of the *winter solstice.*

The *obliquity of the ecliptic* is steadily changing so that the *winter solstice* is not a point of fixed *declination.* When the Tropic of Capricorn is to be shown on a terrestrial *map,* it is desirable that it be treated as a line of fixed *latitude,* and for this purpose it is here proposed that the value 23°27′ south *latitude* be adopted and used. See supplementary paragraph under *Tropic of Cancer.*

tropical month.—See under *month.*

tropical year.—See under *year.*

Troughton level.—See under *leveling instrument.*

true.*—A comparative term applied to astronomical values to distinguish them from corresponding magnetic values.

The terms *true bearing,* true meridian, true north, etc., occur frequently in land survey reports, distinguishing those quantities from corresponding magnetic values. In descriptions of land boundaries, the use of true has legal significance and, except in rare instances, refers to values based directly on astronomical observations. True should never be used to indicate *geodetic* values, although in recent work, where the difference between astronomical and *geodetic* values is unimportant, the term has been applied without distinction to both in order to distinguish them from corresponding magnetic values. The use of true to indicate astronomical values should be avoided as much as possible: exact meaning is conveyed by the terms *celestial meridian, geodetic meridian, magnetic meridian,* etc.

true bearing.—See under *bearing.*

true error.—See under *error (general).*

true solar time.—See under *time: apparent solar time.*

turning point (leveling).—See under *point.*

U

Unalaska datum.—See under *datum.*

unit: absolute.—Any unit in a system that is based directly upon associated fundamental units of length, mass, and time.

In selecting a system of absolute units, the choice of the fundamental units is arbitrary. In the metric (c. g. s.) system of absolute units, the fundamental units are the centimeter, the gram, and the second. In the *leveling* work of the U. S. Coast and Geodetic Survey, the metric system is used in defining *dynamic number.*

unit: astronomical.—See under *astronomical unit.*

unit of length.—A nominal distance in space fixed by definition, and independent of temperature, pressure, and other physical conditions. See *meter: international meter; standard of length.*

U. S. Coast and Geodetic Survey leveling rods.—See under *leveling rod: U. S. Coast and Geodetic Survey rods.*

U. S. Engineer leveling rod.—See under *leveling rod: U. S. Engineer precise leveling rod.*

U. S. Geological Survey level.—See under *leveling instrument.*

U. S. Geological Survey leveling rods.—See under *leveling rod: U. S. Geological Survey precise leveling rods.*

United States standard datum.—See under *datum: North American datum.*

universal instrument.—See under *alt-azimuth instrument.*

universal level.—See under *level: circular level.*

universal time.—See under *time.*

upper culmination.—See under *culmination.*

V

Valdez datum.—See under *datum.*

value (of a quantity).—An arithmetical number which defines the size of the quantity.

value: adjusted.—A *value* of a quantity derived from observed data by some orderly process which eliminates *discrepancies* arising from *errors* in those data.

The process, called an *adjustment,* may be made by graphical (mechanical) methods or by analytical (arithmetical) methods. An analytical method involves the determination of *discrepancies* which exist among combinations of observed data; expressing those discrepancies in the form of *condition equations* or *observation equations;* and solving those equations to obtain *corrections* to the observed data. If the solution is by the *method of least squares,* the result will be the *most probable values* that can be derived from the given data. If the data used are sufficiently extensive, the values obtained by the *least-squares method* will be largely free from *accidental errors* of observation. See *position: adjusted.*

value: most probable.—That *value* of a quantity which is mathematically determined from a series of observations and is more nearly free from the effects of *blunders* and *errors* than any other *value* that might be derived from the same series of observations.

An *adjusted value* determined by the *method of least squares* is a most probable value.

value: observed.—A *value* of a quantity that is obtained by instrumental measurement of the quantity.

The term observed value is often applied to the *value* of a quantity derived from instrumental measurement after corrections have been applied for *systematic errors,* but before *accidental errors* have been taken out by some method of adjustment. An *angle* obtained with a *repeating theodolite,* after correction for *closure of horizon* has been applied, is considered an *observed angle.* See *value: most probable value; value: adjusted value.*

value: true.—That *value* of a quantity which is completely free from *blunders* and *errors.*

Since the *errors* to which physical measurements are subject cannot be known exactly, it follows that the true value of a quantity cannot be known with exactness. In *survey* work, the *most probable value* is used as best representing the true value of the quantity.

variation: magnetic.—See under *magnetic variation.*

variation of latitude.—See under *latitude.*

variation of the pole.—A wandering of the poles of figure of the earth with respect to its poles of rotation.

The direction in space of the poles of *rotation* of the earth is nearly invariable; these are the points on the *celestial sphere* reached by the axis about which the earth rotates. The axis of figure of the earth or axis within the earth about which the moment of inertia is a maximum is not coincident with its axis of *rotation*, and extended to the *celestial sphere* describes a path thereon about each pole of *rotation*—a path which is irregular, although an annual periodicity in the motion may be detected, and also one of 14 months. The maximum variation in direction of the axis of figure from a mean position with respect to the axis of *rotation* ranges between 0.1″ and 0.3″. Variation of the pole affects observed determinations of *astronomic latitude, longitude,* and *azimuth,* but account of it is taken in *first-order work* only.

vernal equinox.—See under *equinox.*

vernier.—An auxiliary scale sliding against and used in reading a primary scale. The total length of a given number of *divisions* on a vernier is equal to the total length of one more or one less than the same number of *divisions* on the primary scale.

The vernier makes it possible to read a principal scale (such as a divided circle) much closer than one *division* of that scale. If a space on the vernier is shorter than a space on the primary scale, it is a direct vernier; if a space on the vernier is the longer, it is a retrograde vernier, so-called because its numbers run in the opposite direction from those on the primary scale. The direct vernier is the usual type, and is used in reading the circles on an engineer's *transit,* and on a *repeating theodolite.* Two verniers extending and numbered in opposite directions from the same initial form a double vernier, used in reading a circle having *graduations* numbered in both directions. A single vernier so constructed and numbered that it may be read in either direction is called a folding vernier.

vernier: contact.—The usual type of *vernier,* having the *vernier* scale and the graduated circle in physical contact.

vernier: direct.—See *vernier.*

vernier: double.—See *vernier.*

vernier: folding.—See *vernier.*

vernier: optical.—A microscope with *vernier* lines ruled on a glass slide placed in the focal plane common to the objective and the eyepiece, where it is compared with the image of the graduated circle.

The microscope is so adjusted that the image of the graduated circle falls in the plane of the *vernier* lines, and the *vernier* scale subtends the proper number of *divisions* of the graduated circle. The optical vernier is superior to the usual *vernier* (*contact vernier*) in that there are no *parallactic errors* such as are caused by wear of the contact edges. Optical verniers are, however, more liable to injury and to loss of adjustment than are *contact verniers.*

vernier: retrograde.—See *vernier.*

vertex of curve.—See under *curve: point of intersection.*

vertical.—The *direction* in which the force of gravity acts.

It is the *direction* indicated by a plumb line, and does not usually coincide with the *direction* of the *normal* at a point. The term vertical uses the *geoid* as a reference; *normal* applies to the *spheroid.* See *zenith* and *nadir;* and *deflection of the plumb line.*

vertical angle.—See under *angle.*

vertical angulation.—The process of obtaining differences of *elevation* by means of observed *vertical angles,* combined with lengths of lines.

In *geodetic* work, *trigonometric leveling* is used with the same meaning.

vertical axis (theodolite; transit).—The line through the center of instrument about which the *alidade* rotates.

For an instrument in complete adjustment, this axis occupies a vertical position, passes through the center of the horizontal circle, and is perpendicular to its plane.

vertical circle.—Any *great circle* of the *celestial sphere* passing through the *zenith* (and *nadir*). Also, a divided circle mounted on an instrument in such a manner that the plane of its graduated surface can be placed in a *vertical plane.*

As a *great circle,* a vertical circle is the line of intersection of a *vertical plane* with the *celestial sphere.* As an instrument, a vertical circle may be an auxiliary attachment to a *theodolite* or *transit,* or it may be the major feature of an instrument intended primarily for use in measuring *vertical angles* in astronomical and *geodetic* work. In *geodetic* work, such an instrument is called a vertical circle.

vertical collimator.—See under *collimator.*

vertical comparator (pendulum).—A stand designed for the support of a *pendulum,* a bar of known length, and two *micrometer microscopes,* so placed with reference to one another that the length of the *pendulum* can be measured. Such an apparatus was designed by Repsold.

vertical coordinate.—See under *coordinates.*

vertical plane.—Any plane passing through a point on the earth and containing the *zenith* (and *nadir*) of that point.

Containing the *zenith,* a vertical plane must also contain the *nadir.* The planes of the *celestial meridian* and of the *prime vertical* are vertical planes.

vibration (pendulum).—A single movement of a *pendulum* in either direction, to or fro. See *oscillation (pendulum).*

vibration: amplitude of vibration (pendulum).—See under *amplitude of vibration (pendulum).*

vinculum.—A short horizontal bar placed over the seconds of a numerically expressed *angle* or *direction* to indicate that the seconds are used in connection with a value of minutes 1 less than is recorded. A double vinculum indicates association with a value of minutes 2 less than is recorded.

In recording an *angle* or a *direction* observed with an instrument provided with means of making several independent readings of the circle, as with several *verniers* or *micrometer microscopes,* the degrees, minutes, and seconds are usually recorded for only one *vernier* or microscope, and only the seconds for the other *verniers* or microscopes. Where the seconds as read for the B vernier are associated with minutes less than those recorded for the A vernier, this is indicated in the record by placing a vinculum, or rarely, a double vinculum, over the seconds reading of the B vernier, thus:

	Vernier reading			*Simplified recording*		
	°	′	″	°	′	″
A	90	11	00	90	11	00
B	270	10	50			$\overline{50}$
A	75	15	00	75	15	00
B	255	13	55			$\overline{\overline{55}}$

W

war time.—See under *time.*

Washington Meridian.—See under *meridian.*

water leveling.—See under *leveling.*

weight (surveying).—The relative reliability (or worth) of a quantity as compared with other *values* of the same quantity.

If one *value* of a quantity has a weight of 2, and another *value* of the same quantity has a weight of 1, the first *value* is worth twice the second *value,* and a mean *value* would be obtained by taking a *weighted mean:* twice the first *value* plus once the second *value,* the sum being divided by three.

weighted mean.—A value obtained by multiplying each of a series of *values* by its assigned *weight,* and dividing the sum of those products by the sum of the *weights.*

A weighted mean is sometimes called a weighted arithmetical mean. If the constituent *values* are all of the same *weight,* the *weight* of each *value* may be considered as unity, and an *arithmetical mean* taken. The present practice in *surveying* where both instruments and methods are *standard,* is to make all observations of the same (unit) *weight,* thereby simplifying the computations involved in their reduction and adjustment.

Werner map projection.—See under *map projection.*

westing.—See under *departure (plane surveying).*

Wild theodolite.—See under *theodolite.*

wind (spirit level).—See under *level.*

winter solstice.—See under *solstice.*

witness corner.—A marked point established on firm ground at a measured distance and *direction* from a property corner which may be so situated that it cannot be permanently marked.

A witness corner in *land surveying* corresponds to a *reference mark* in *control surveying.* See *corner: witness corner (United States public-land surveys).*

witness corner (United States public-land surveys).—See under *corner.*

witness mark.—A material mark placed at a known distance and *direction* from a property corner, instrument or other *survey station,* to aid in its recovery and identification.

In *surveying,* a witness mark is established as an aid in the recovery and identification of a *survey station,* or other point to which it is a witness. A mark which is established with such *precision* and *accuracy* that it may be used to restore or take the place of the original station is more properly called a *reference mark* in *control surveys,* and a *witness corner* in *land surveys.*

Woodward base-line measuring apparatus.—See under *base apparatus: iced-bar apparatus.*

working pendulum.—See under *pendulum.*

wye (Y) level.—See under *leveling instrument.*

X

***x* correction.**—The *correction* to an *x direction.*

***x* direction.**—An observed *direction* in a *triangulation* figure for which an approximate value is obtained and treated like an observed *direction* in the adjustment of the figure.

The work of a *least-squares* adjustment of a *triangulation* figure sometimes requires the use of an *x* direction, for which an approximate value is obtained by an *inverse position computation,* by the solution of the *three-point problem,* or by other means, and then using this *x* direction in the adjustment and obtaining a *correction* (*x correction*) for it, which makes it consistent with the adjusted values of the observed *directions.*

Y

Y (wye) level.—See under *leveling instrument: wye (Y) level.*

Yakutat datum.—See under *datum.*

yard.—A unit of length equal to 36 *inches* exactly.

year.—An interval of *time* based on the *revolution* of the earth in its orbit around the sun with respect to (1) the stars, giving the *sidereal year;* (2) the *vernal equinox,* giving the *tropical year;* (3) *perihelion,* giving the *anomalistic year.* There is also a *calendar year,* a conventional value based on the *tropical year.*

year: anomalistic.—The interval of *time* between two successive passages of *perihelion* by the sun.

The anomalistic year is equal to 365.25964 *mean solar days.*

year: calendar.—A conventional *year* based on the *tropical year.*

The calendar year takes account of the fraction of a *day* contained in the *tropical year,* by assigning an additional *day* to the *year* at stated periods. The calendar years of interest in this country are defined by the *Julian Calendar,* and the *Gregorian Calendar.*

year: sidereal.—The interval of *time* occupied by the sun in completing an apparent circuit of the heavens, from a given star back to the same star.

The sidereal year is equal to 365.25636 *mean solar days.*

year: tropical.—The interval of *time* between two successive passages of the *vernal equinox* by the sun.

The tropical year is the *year* of the seasons, and the basis of the conventional *calendar year* used in chronology and civil reckoning. It is equal to 365.24220 *mean solar days.*

Yukon datum.—See under *datum.*

Z

zenith.—The point where the *direction* of the plumb line produced above the *horizon* meets the *celestial sphere.*

The zenith and *nadir* are poles of the *horizon.* The plumb line is perpendicular to the surface of the *geoid,* but not (except in rare cases) to the surface of the *spheroid.* The *angle* between the plumb line (the *vertical*) and the perpendicular to the surface of the *spheroid* (the *normal*) is the *deflection of the vertical,* also called the *deflection of the plumb line.* The terms, *geodetic zenith* (or *nadir*) and *geocentric zenith* (or *nadir*) are sometimes used, and with meanings different from the above definition: their use is not recommended.

zenith: geocentric.—The point where a line from the center of the earth through a point on its surface meets the *celestial sphere.*

This term is sometimes used in astronomic work, but seldom appears in *geodetic* work. It should be used only in its entirety, the single word, *zenith,* being reserved to designate the point determined by the *direction* of the plumb line.

zenith: geodetic.—The point where the *normal* (to the *spheroid*) extended upward, meets the *celestial sphere.*

This term has some use in *geodetic* work, but should be used only in its entirety. The single word, *zenith,* is reserved to designate the point determined by the *direction* of the plumb line.

zenith camera.—An instrument for the determination of an astronomic position by taking a photograph of the sky immediately surrounding the *zenith.*

The instrument consists of a camera designed to photograph a small section of the sky. The optical axis may be set very precisely in the vertical so that the photograph is symmetrical with respect to the observer's zenith. The time of each observation is recorded on the photograph, thus furnishing the information required to compute the astronomic latitude and longitude.

zenith distance.—The *vertical angle* between the *zenith* and the object which is observed or defined. See *zenith distance: double.*

Zenith distance is the complement of the *altitude.*

zenith distance: double.—A value of twice the *zenith distance* of an object, obtained by observation and not by mathematical process.

In *trigonometric leveling* and in astronomical work, double zenith distances are observed because they are nearly free from effects of inclination of the *vertical axis* of the instrument used.

zenith sector.—See under *sector.*

zenith telescope.—A portable instrument adapted for the measurement of small differences of *zenith distance,* and used in the determination of *astronomic latitude.*

This instrument consists of a *telescope* equipped with an *ocular micrometer* and a *spirit level,* and so mounted on a *vertical axis* that it may be placed in the plane of the *meridian* for observation on a star *culminating* north (or south) of the *zenith,* and then rotated 180° in *azimuth* and a second star observed as it *culminates* south (or north) of the *zenith.* The difference of the *zenith distances* of the two stars is measured with the *micrometer;* the *spirit level* is used to determine any change that may occur in the direction of the axis of *rotation* of the *telescope* between the two observations. In its present form, this instrument is essentially the invention (in 1834) of Captain Andrew Talcott of the U. S. Engineers. It was adopted by the U. S. Coast and Geodetic Survey for *latitude* determinations and given some improvements. See *zenith-telescope method, latitude determinations.*

zenith-telescope method, latitude determination.—A *precise* method of determining *astronomic latitude* by measuring the difference of the meridional *zenith distances* of two stars of known *declination,* one north and the other south of the *zenith.*

The observations are made with a *zenith telescope,* or with an *astronomical transit* which can be converted to serve as a *zenith telescope,* such as the *meridian telescope* and the *broken-telescope transit.* The two stars have approximately the same meridional *zenith distances,* and their *culminations* occur within a few minutes of the same time. The *astronomic latitude* of the point of observation will be one-half the sum of the *declinations* of the two stars, plus or minus one-half the difference of their *zenith distances.* This method is also known as the Horrebow-Talcott method, latitude determination, and the Talcott method, latitude determination. While Peter Horrebow (not Harrebow) published an account of his method in 1732, it was buried in obscurity, and there is good reason to believe that Captain Andrew Talcott had no knowledge of Horrebow's work when he announced his own discovery of the method in 1834.

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