SVEUČILIŠTE U ZAGREBU
GEODETSKI FAKULTET

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TECHNICAL ENGLISH IN SURVEYING

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PREFACE

This textbook is primarily intended for students studying geodesy and who have eight years of general English at school. It covers the course and examination programme for the subject *English language*.

Learning technical English is considered as integrated process requiring varied cognitive capabilities and skills: reading comprehension, the writing and speaking that are involved in the communication process as aspects of linguistic knowledge. The capabilities and skills have already been acquired in the student's native technical language and should be targeted in technical English also. This requires an attempt to develop greater student sensitivity to the way of thinking in engineering technical English as one variant of English, a language that prefers a certain specific discourse and syntactic structures to others. Technical terminology is also a characteristic of technical English. My attempt is to make the student competent to read and comprehend scientific/engineering data found in professional journals. Writing, at least at the level of writing abstracts, is also indispensable, since abstract is always included in papers or articles published in Croatian or international professional journals.

I hope that this teaching approach and this textbook offering various aspects of technical English in surveying will help students to orient themselves in professional texts, to read them with comprehension, to communicate orally, and to write an abstract of an engineering text. The topics in this book have been chosen from the specific areas a surveying engineer may encounter. The texts include about 300 specialist terms.

This textbook is an example of my work with students of surveying at the Faculty of Geodesy, at the University of Zagreb.

Zagreb, 2007. Biserka Fučkan Držić

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Lesson 1

Definition and Classification of Geodesy

According to the classical definition of F.R. Helmert, geodesy is "the science of the measurement and mapping of the earth's surface". This definition has to this day retained its validity. It includes the determination of the earth's external gravity field, as well as the surface of the ocean floor. With this definition, geodesy may be included in the geosciences, and also in the engineering sciences.

Triggered by the development of space exploration, geodesy turned in collaboration with other sciences toward the determination of the surfaces of other heavenly bodies (moon, other planets). The corresponding disciplines are called selenodesy and planetary geodesy.

Geodesy may be divided into the areas of global geodesy, geodetic surveying, and plane surveying. Global geodesy is responsible for the determination of the figure of the earth including the complete external gravity field. A geodetic survey defines the surface of the country by the co-ordinates of a sufficiently large number of control points. In this fundamental work, the overall curvature of the earth must be considered. In Plane surveying (topographic surveying, cadastral surveying, engineering surveying), the details of the land surface are obtained. The horizontal plane is in general sufficient as a reference surface.

There is a close interaction between global geodesy, geodetic surveying and plane surveying. The geodetic survey adopts the parameters determined by measurements of the earth, and its own results are available to those who measure the earth. The plane surveys, in turn, are generally tied to the control points of the geodetic surveys and serve then particularly in the development of national map series and in the formation of real estate cadastres.

The concept of "geodesy" is to be referred only to global geodesy and geodetic surveying. The concept of "surveying" shall encompass plane surveying. Speaking in general, the major task of geodesy is to determine the figure and the external gravity field of the earth and of other heavenly bodies as functions of time, as well as to determine the mean earth ellipsoid from parameters observed on and exterior to the earth's surface.

Selenodesy is the branch of applied mathematics which determines, by observation and measurements, the exact positions of points and the figures and areas of large portions of the moon's surface, or the shape and size of the moon.

EXERCISES AND DRILL

I Comprehension questions

1. How did F.R. Helmert define geodesy?
2. What makes geodesy one of the geosciences and also one of the engineering sciences?
3. Is geodesy dealing only with the exploration of the earth?

4. What is the difference between global geodesy and geodetic surveying on one hand and plane surveying on the other?
5. Describe the connection between the three areas of geodesy!

II Complete these sentences with one of the words below!

1. _______________ is the field of force arising from a combination of the mass attraction and rotation of the earth.

2. Generally speaking, the task of the surveyor is to ______________relative positions of points above, on or beneath the surface of the earth.

3. The data necessary for accomplishing the geodetic task are ________________in the field work.

4. There is an ______________between geodesy and the corresponding disciplines like selenodesy and planetary geodesy.

5. The ______________ must be taken into account in geodetic surveying.

determine, interaction, obtain, curvature, gravity field

III Fill in the correct form of the verb!

1. Mathematics _________ never been my favourite subject.
2. The news printed in that journal ______never accurate.
3. A second series of books on photogrammetry _______ being planned by the publisher.
4. There _______several means of accomplishing our purpose.
5. Ten minutes _______ too short a time to finish this test.
6. The premises of our Faculty _______been cleared of students because of a bomb threat.

IV Translate the following text into Croatian.

Surveying has traditionally been defined as the science, art, and technology of determining relative positions of points above, on, or beneath the surface of the earth, or establishing such points. In a more general sense, however, surveying can be regarded as that discipline which encompasses all methods for gathering and processing information about the physical earth and environment. Surveying is one of the world's oldest and most important arts because from the earliest times it has been necessary to mark boundaries and divide land. Surveying has now become indispensable to our modern way of life. The results of today's surveys are being used to map the earth above and below sea level, prepare navigational charts for use in the air, on land and at sea, establish property boundaries of private and public lands, develop data banks of land-use and natural resource information which aid in managing our environment, determine facts of the size, shape, gravity and magnetic fields of the earth and prepare charts of our moon and planets.

INFINITIVE

Frequently a clause having the same subject as the main sentence can be more concisely expressed by using an infinitive

Example: The results of today's surveys are being used *to map the earth above and below the sea level.*

Notice also its use after a superlative:
He was the first man to make this remark.

Reword the following sentences using the infinitive:

1. He was sorry when he heard of your disappointment.
2. From the earliest times it was necessary that the boundaries be marked and the land divided.
3. Surveyor has to make research analysis and appropriate decision if he wants to do his job properly.
4. When a map, plat or chart is produced, the plotting measurements have to be performed for that purpose.
5. If you to determine the area of a continent, the curved surface of the earth is considered.

Lesson 2

The Surveying Profession

1. What do you think about the profession of a surveyor?
2. Do you know what tasks a surveyor performs in his work?

Land or boundary surveying is classified as a learned profession because the modern practitioner needs a wide background of technical training and experience and must exercise a considerable amount of independent judgement. Registered (licensed) professional surveyors must have a thorough knowledge of mathematics - particularly geometry and trigonometry with some calculus; a solid understanding of surveying theory, instruments and methods in the areas of geodesy, photogrammetry, remote sensing, cartography and computers; some competence in economics (including office management, geography, geology, astronomy and dendrology; and a familiarity with laws pertaining to land and boundaries. They should be knowledgeable in field operation and computations and able to do neat drafting. Above all, they are governed by a professional code of ethics, and are expected to charge reasonable fees for their work.

The personal qualifications of surveyors are as important as their technical ability in dealing with the public. They must be patient and tactful with clients and their sometimes hostile neighbours. Few people are aware of the painstaking research of old records before field work is started. Diligent, time-consuming effort may be needed to locate corners on nearby tracts for checking purposes as well as to find corners for the property in question.

Permission to trespass on private property or to cut obstructing tree branches and shrubbery must be obtained through a proper approach. Such privileges are not conveyed by a surveying license or by employment in a state highway department (but a court order can be secured if a landowner objects to necessary surveys).

To qualify for registration as either a professional Land Surveyor (LS) or an Engineer (PE) in the USA it is necessary to have an appropriate college degree. In addition, candidates take a Surveyor-in-Training (SIT) or Engineer-in-Training (EIT) test, acquire two or more years of additional practical experience, and then must pass a two-day written examination.

Future Challenges in Surveying

Surveying has experienced a revolution in the way data are stored, retrieved and shared. This is due in large part to developments in computer technology. The demands on surveyors will be very different in a few years from what they are now.

The geodetic control network must be maintained and supplemented to meet requirements of high-order future surveys. New topographic maps with larger scales, and digital map products, are necessary for better planning and design. Existing maps of our rapidly expanding urban areas need revision and updating to reflect changes, and more and better map products are needed in our older cities to support urban renewal programs and infrastructure maintenance and modernisation.

Long-range planning and assessment of environmental impacts of proposed construction projects call for maps and other data. Land Information Systems and Geographic Information Systems that contain a variety of land-related data such as ownership, location, acreage, soil types, land uses and natural resources must be designed, developed and maintained. Cadastral surveys of the yet unsurveyed public lands are essential. Monuments set many years ago by the original surveyors have to be recovered and remonumented for preservation of property boundaries. Appropriate surveys with very demanding accuracies are necessary to position drilling rigs as mineral and oil explorations press farther offshore. And in the space program, the desire for maps of neighbouring planets will continue.

EXERCISES AND DRILL

I Answer the following questions!

1. What makes surveying a learned profession?
2. Name the subjects that surveyor must have thorough knowledge in?
3. In what way is code of ethics important for any profession?
4. What else is important for surveyors besides their technical ability?
5. Which problems does surveyor need to settle on his own?
6. What is needed to get qualifications for registration as either a professional land surveyor or an engineer in the USA?
7. What do you need to qualify for a professional land surveyor in our country?
8. What kind of influence has computer technology made on surveying?
9. Name a few tasks which are to be executed in the future by surveyors!

II Make questions to which these are the answers:

1. By means of a court order.
2. Because a wide background of technical training and experience is needed.
3. As important as the technical ability in dealing with the public.
4. In the way data are stored, retrieved and shared.
5. Revision and updating to reflect changes.
6. Those that contain a variety of land-related data such as ownership,location, acreage, soil types, land used and natural resources.

III Use the following phrases in the sentences of your own!

1. ABOVE ALL they are governed by a professional code of ethics.
2. Few people are AWARE of the painstaking research of old records.
3. A court order can be secured if a landowner OBJECTS TO necessary surveys.
4. This is DUE in large part TO developments in computer technology.
5. Existing maps need revision and UPDATING to reflect changes.

IV Adding agent-denoting suffixes

Add noun suffixes to the following to denote an agent!

discover biology survey
geodesy operate geometry
observemathematics
surgery depend engineering

V Put hundred/s, thousand/s, million/s in each space below!

1. Ten …....people listened to the speech.
2. ….......of people were at the football match.
3. He has five…......pounds in the bank.
4. There are three ….....boys in this school.
5. How many of …..........stars are there in the sky?
6. They told me that there were more than a hundred …....stars in the universe.
7. He has ….......of pounds in the bank.

VI Translate the following text into Croatian.

As Surveying or, as it is sometimes called, Land Surveying, is a compulsory subject for students of Civil Engineering, and all branches of the Surveying Professions, all such students, as well as those reading for a General Certificate of Education at Advanced Level in Surveying, should benefit from studying the text. Descriptive matter is included only where it helps to clarify surveying principles for – and it cannot be emphasised too much – surveying is a practical subject in which instrument practice is essential.

During the early 1970s industry and, consequently, examinations will be going metric and with this in mind the text has been written with reference only to SI units. All the examples have been rewritten in these units, Imperial units appearing nowhere. The modified questions are base, as in the first edition, largely on questions taken from the old Part II examination, but also, ideas are drawn from questions set in all the examinations referred to above.

Lesson 3

Specialised Surveys

Many types of surveys are so specialised that a person proficient in a particular discipline may have little contact with the other areas. Persons seeking careers in surveying and mapping however should be knowledgeable in every phase, since all are closely related in modern practice. Some important classifications are described briefly here.

Control surveys establish a network of horizontal and vertical monuments that serve as a reference framework for other surveys.

Topographic surveys determine locations of natural and artificial features and elevations used in map making.

Land, boundary and cadastral surveys are closed surveys to establish property lines and corners. There are three major categories: *original surveys* to establish new section corners in unsurveyed areas; retracement surveys, to recover previously established boundary lines; and *subdivision surveys* to establish monuments and delineate new parcels of ownership.

Hydrographic surveys define shorelines and depths of lakes, streams, oceans, reservoirs and other bodies of water. *Sea surveying* is associated with port and offshore industries and the marine environment, including measurements and marine investigations made by shipborne personnel.

Route surveys are made to plan, design, and construct highways, railroads, pipelines and other linear projects. They normally begin at one control point and progress to another control point in the most direct manner permitted by field conditions.

Construction surveys provide line, grade, control elevations, horizontal positions, dimensions and configurations for construction operations. They also secure essential data for computing construction pay quantities.

Mine surveys are performed above and below ground to guide tunnelling and other operations associated with mining, including geophysical surveys for mineral and energy resource exploration.

Solar surveys map property boundaries, solar access easements, position obstructions and collectors according to sun angles.

Optical tooling (also referred to as industrial surveying or optical alignment) is a method of making extremely accurate measurements for manufacturing processes where small tolerances are required.

Ground and aerial surveys are broad classifications sometimes used. Ground surveys utilise measurements made with ground-based equipment such as tapes, electronic distance-measuring device, levels, and theodolites. Aerial surveys may be accomplished by either photogrammetry or remote sensing. Photogrammetry uses cameras that are usually carried in aeroplanes, whereas remote sensing employs cameras and other types of sensors that can be transported in either aircraft or satellites.

EXERCISES AND DRILL

I Comprehension questions

1. In what other occupations is the term *survey* employed?
2. Why is it necessary to make accurate surveys of underground mines?
3. Which kinds of surveys would you classify as "engineering" surveys?
4. Why should a purchaser of a farm, city lot or homed demand a survey before making final payment?

II True or false?

1. Construction surveys are applied in industry.
2. A network of horizontal and vertical monuments that serve as a reference framework for other surveys is established within the scope of cadastral surveys.
3. Route surveying has reference to those surveys necessary for the location and construction of lines of transportation or communication.
4. One of the tasks of land surveying is to subdivide lands into parcels of predetermined shape and size.
5. The work in ground surveys consists in taking photographs from two or more control stations on the ground.

Modal auxiliary verbs

There are only twelve modal auxiliary verbs, but they are used with very great frequency and in a wide range of meanings. They express concepts or attitude relation to recommendation, obligation, necessity, and prohibition; permission and refusal; possibility, expectation, probability and certainty; promise and intention, ability and willingness.
The set of twelve verbs consists of four paired forms - can, could; may, might; shall, should; will, would; and four single forms - must, ought, need, dare. There are no other forms and all models are therefore, to varying degrees, "defective" verbs.

Exp. a) A person proficient in a particular discipline may have little contact with the other areas. (probability)
b) Person seeking career in surveying and mapping should be knowledgeable in every phase. (recommendation)
c) Remote sensing employs camera and other types of sensors that can be transported in an aircraft or satellite. (possibility)

III Fill in the suitable modal verb.

1. Some types of survey ___________very few computations. (necessity)
2. A single reference plan _________be selected for a survey where a survey is of a limited extent. (possibility)
3. In the study of surveying the student __________become familiar with the field operation techniques. (obligation)
4. The control network ___________be maintained and supplemented to meet requirements of high-order surveys. (recommendation)

Lesson 4

History of Surveying

1. Do you know something about the beginnings of geodesy?

Early concept of the figure of the Earth

The question of the figure of the earth had already been raised in antiquity. It provoked various opinions on the form of the earth. Early civilisation assumed the earth to be a flat surface, but by noting the earth's circular shadow on the moon during the lunar eclipses and watching ships gradually disappear as they sailed toward the horizon, it was slowly deduced that the planet actually curved in all directions introducing thus the notion of an earth disc encircled by Oceanus. Pythagoras (580-500 BC) and his school, as well as Aristotle (384-322 BC), among others, expressed themselves for spherical shape.

Eratosthenes' method for determining the size of the Earth

Determining the true size and shape of the earth has intrigued humans for centuries. The founder of the scientific geodesy is Eratosthenes (276-195 BC) of Alexandria, who under the assumption of a spherical earth deduced from measurements a radius for the earth. The principle of the arc

Fig. 1 Illustration of Eratosthenes's technique of computing the earth's circumference

measurement method developed by him was still applied in modern ages. From geodetic measurements, the length ΔG of a meridian arc is determined. Astronomical observations furnish the associated central angle γ (Fig. 1). The radius of the earth is given by $\frac{\Delta G}{\gamma}$.

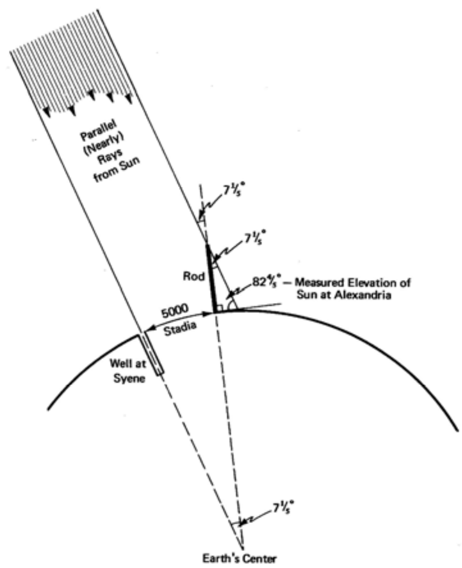

Fig. 1 Illustration of Eratosthenes's technique of computing the eath's circumference

Eratosthenes found that at the time of the summer solstice, the rays of the sun descended vertically into a well in Syene (Assuan, today), whereas in Alexandria, roughly on the same meridian, they formed an angle with the direction of the plumb line. From the length of the shadow of a vertical staff produced in a hemispherical shell, he determined this angle as 1\50 of a complete circle, i.e. $\gamma = 7°12'$. He estimated the distance from Syene to Alexandria to be 5000 stadia as taken from Egyptian cadastre maps that are based on the information of step counters. With the length of an Egyptian stadium as 157.5 m, we obtain an earth radius of 6267 km. This value departs from the radius of a mean spherical earth (6371 km) by - 2%.

The beginnings of surveying in Egypt

The oldest historical records in existence today that bear directly on the subject of surveying state that this science had its beginning in Egypt. Herodotus recorded that Sesostris (about 1400 BC) divided the land of Egypt into plots for the purpose of taxation. Annual floods of the Nile River swept away portions of these plots and surveyors were appointed to replace the bounds. These early surveyors were called rope-stretchers (harpedonapata), since their measurements were made with ropes having markers at unit distances.

Greek thinkers

As a consequence of this work, early Greek thinkers developed the science of geometry being the term in Greek for "earth measurement" (Gr. *geōmetria* < *geōmetrein,* to measure the earth <gē, earth + *metria*, measurement) clearly showing the relationship between mathematics and surveying. Their advance, however, was chiefly along the lines of pure science. Heron stands out prominently for applying science to surveying in about 120 BC He was the author of several important treatises of interest to surveyors, including *The Dioptra*, which related the methods of surveying a field, drawing a plan, and making calculations. It also described one of the first pieces of surveying equipment recorded, the diopter. For many years Heron's work was the most authoritative among Greek and Egyptian surveyors.

Practical mindend Romans

Significant development in the art of surveying came from the practical-minded Romans. Their engineering ability was demonstrated by their extensive construction work throughout the empire. Surveying necessary for this construction resulted in the organisation of a surveyor's guild. Ingenious instruments were developed and used. Among these were the groma, used for sighting; the libella, an A frame with a plumb bob, for levelling; and the chorobates, a horizontal straightedge about 20 ft long with supporting legs and a groove on top for water to serve as a level.
Little progress was made in the art of surveying during the Middle Ages and the only writing pertaining to it were called "practical geometry".

Scientific revolution

The sixteenth and seventeenth centuries brought new observations and ideas from astronomy and physics which influenced decisively the perception of the figure of the earth and its position in the space. N. Copernicus (1473-1543) achieved the transition from the geocentric universe of Ptolemy to a heliocentric universe. In the 17th century Isaac Newton developed earth models flattened at the poles. In 1687 Newton obtained a rotational ellipsoid as a figure for a homogeneous, fluid rotating earth based on the validity of the law of universal gravitation.

18th and 19th centuries and modern times

In the eighteenth and nineteenth centuries the art of surveying advanced more rapidly. The need for maps and location of national boundaries caused England and France to make extensive surveys requiring accurate triangulation; thus geodetic surveying began.

Increased land values and the importance of exact boundaries, along with the demand for public improvements in the canal, turnpike and railroad areas, brought surveying into a prominent position. More recently, the large volume of general construction, numerous land subdivisions with better record required, and demands posed by the fields of exploration and ecology have entailed an augmented surveying program. Surveying is still the sign of progress in the development and use of the earth's resources.

Modern times bring the progress continuing into the space program where new equipment and systems were needed to supply precise control for missile alignment and moon mapping of proposed landing sites. Electronic distance-measuring equipment, laser devices, north-seeking gyroscopes, improved aerial cameras, helicopters, inertial and satellite surveying systems, remote sensors, and various-size computers are but a few products of today's technology now being directly applied in modern surveying.

EXERCISES AND DRILL

I True or false statements?

1. Pythagoras was the founder of scientific geodesy.
2. Plumb line is geometric figure that consists of a point together with all points on a line that lie in the same direction from the endpoint.
3. Summer solstice is the point on ecliptic occupied by the sun at maximum northerly declination.
4. The arc length was found out in Egypt by multiplying the number of caravan days between Syene and Alexandria by average daily distance travelled.
5. Stadium is a unit of angle measurement.
6. There was no progress in surveying in the 17th and 18th centuries.
7. Geodetic work has become computer-aided very early because of numerous calculations involved in it.

II Answer these questions:

1. What does the history record about the beginnings of surveying?
2. What were the early surveyors called and why had they been appointed?
3. How did the Greek contribute to the development of surveying?
4. What caused a significant development of surveying during the Roman times?
5. Which instruments were developed and used by Roman surveyors?
6. What made the people change their belief that the earth was flat?
7. How did Eratosthenes compute the circumference of the earth? Was it a correct value?
8. What made the art of surveying advance more rapidly in the 18th and 19th century?
9. How did modern times affect the progress of surveying?

III Look at the use of tenses in these sentences!

1. The oldest historical records in existence today which bear directly on the subject of surveying state that this science had its beginning in Egypt.
2. Early Greek thinkers developed the science of geometry. Their advance, however, was chiefly along the lines of pure science. Heron stands out prominently for applying science to surveying in about 120 BC
3. Determining the true size and shape of the earth has intrigued humans for centuries.

Say which tenses have been used in the sentences above and why!
Find 4 sentences of your own in the text and explain the usage of the tenses.

IV Put the verbs in brackets into correct Tense!

Man ___________ (to be concerned) about the Earth on which he ______(live) for many centuries. During very early times this concern ______________(to be limited), naturally, to the immediate vicinity of his home; later it _______________(expand) to the distance of markets or exchange places; and finally, with the development of means of transportation man ______________(become) interested in his whole world. Much of this early "world interest" _________________(to be evidenced) by speculation concerning the size, shape, and composition of the Earth.

Primitive ideas about the figure of the Earth, still found in young children, _____________8hold) the Earth to be flat, and the heavens a physical dome spanning over it. Lunar eclipses, e.g., always _________(happen) when the Earth is between Sun and Moon, it ___________(suggest) that the object casting the shadow _______________(be) the Earth and must be spherical (and four times the size of the Moon, the lunar and solar disc being the same size). Also an astronomical event like a lunar eclipse which ______________(happen) high in the sky in one end of the Mediterranean world, ____________(be) close to the horizon in the other end, again suggesting curvature of the Earth's surface.

V Insert the correct prepositions in the blanks:

1. I am sure that his remark bears _____ my behaviour last night.
2. Geometry is usually applied _____ sciences like geodesy, architecture etc.
3. His efforts resulted ____ the book that was published lately.
4. The result was calculated ______the measurements done previously on the adequate location.
5. Eratosthenes stands out _____calculating the earth's circumference.

VI Find the synonyms in the text for the words underlined in the sentences below!

1. His book testifies about the events from the war.
2. A lot of skilfully made household machines have changed the life of a housewife a great deal.
3. Buses in London have taken the place of trams.
4. His plans have made great expenses necessary.

VII Replace the underlined words with the synonyms below.

1. Under the assumption of a spherical earth, Eratosthenes deduced a radius of the earth.
2. Astronomical observations furnish the associated central angle.
3. Existing maps need updating.
4. The engineering activity of Romans influenced the development of surveying in that time.
1. The distance from Syene to Alexandria was taken from Egyptian cadastre maps.

bringing up to date; constructing; land register; presumption

Lesson 5

Geometric Figures

Geometry is the branch of mathematics that deals with points, lines, surfaces and solids and examines their properties, measure, measurement and mutual relations in space.

A plane is a flat surface. No surface in nature, under microscopic examination, would be found to be perfectly flat, but we can imagine the existence of such an ideal surface, and we can use our paper or chalkboard as a representation of that surface. On our plane we can mark a location: a point. The mark we make, although small, is not really a point, for a true point has no size at all. Our mark is merely a representation (a "picture") of a point.

The entire plane consists of an infinite number of points. Any collection or grouping of these points is called a geometric figure. A point is the most elementary or fundamental geometric figure. We can "draw a picture" of a point by making a small dot on our paper, or chalkboard, or whatever we are doing to represent the plane that contains the point. To identify a point in a drawing, or when talking or writing about the point, it is often best if the point is given a name. Here we will follow the customary practice or using capital letters to name points.

Imagine that we take a "perfect pencil" (one whose tip is a true "point) and move it along our plane, causing it to leave a mark as it moves. Every location on that mark is a point, and this collection of points is another type of geometric figure: a curve. If, as we moved the pencil, we never changed the direction of motion, then the mark made would be a representation of part of a straight line (or just line). The entire straight line extends forever in opposite directions, but since our representation of the plane is limited, we can draw a picture of only part of the line.

Applications of geometry involve only parts of lines rather than entire lines. A line segment consists of two points on a line (these pints are the "endpoints" of the segment) together with all points of the line that lie between the endpoints.

Naming angles

A ray is a geometric figure that consists of a point (the "endpoint" of the ray) together with all points on a line that lie in the same direction from the endpoint.

An angle is a geometric figure formed by joining two rays that have the same endpoint. The common endpoint of the rays is called the vertex of the angle. (The plural of "vertex" is "vertices".) The two rays are called the sides of the angle.

An angle is defined once the two rays that form the angle's sides are known. If two segments contain a common endpoint, then those segments also define an angle, for if the segments were extended indefinitely in directions away from their common endpoint then they would form rays, which would form an angle. It is not necessary to actually extend the segments - we can merely imagine extending them. In a similar way, two intersecting lines define four rays, having as a common endpoint the point where the lines intersect. These rays, joined in pairs, define several angels.

Measures of angles

Suppose one ray of an angle is held fixed, but the other ray is hinged at the vertex and allowed to rotate. A measure of an angle is a number, together with some "unit of angular measure", that tells how much the "hinged ray" would need to be rotated so that it would overlie the other ray. If one ray lies directly on top of another ray, then the rays are said to be "coincident". If a ray is rotated one revolution ("all the way around") then it will be coincident with its original position. A possible unit for measuring angles is revolution.

A more commonly used unit for measuring angles is degrees. A rotation of 360 degrees is the same as a rotation of one revolution, a fact that is stated in the following conversion equation:

1 revolution = 360 degrees

1\rev = 90º Any angle having a measure of 90º is called a right angle.

1\2 rev = 180º Any angle having a measure of 180º is called a straight angle.

The sides of a right angle are said to perpendicular. The word "perpendicular" can be used to describe the relationship between two lines, rays or segments that meet so as to form a right angle.

The definitions of "right angle" and "straight angle" are given again in the box below, together with the definitions of some other words that give information abut an angle's measure.

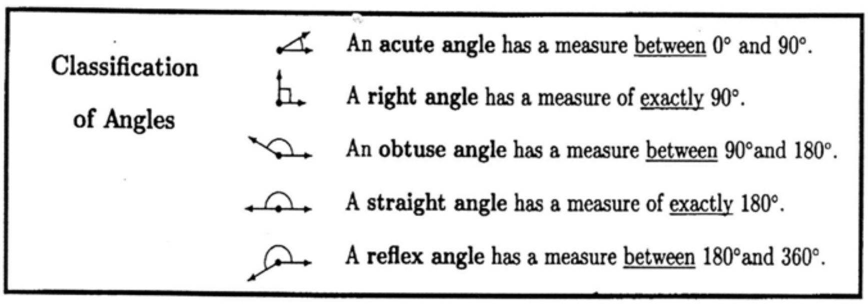

Fig. 2 Definitions of angles

Special words describe the relationship between two angles whose measures have a sum of either 90º or 180º:

Two angles are complementary angels if their measures have a sum of 90º.
Two angles are supplementary angles if their measures have a sum of 180º.

Sometimes the knowledge of the measure of one or more angles in a geometric drawing will enable you to determine the measures of other angles.

EXERCISES AND DRILL

I True or false?

1. A point has its size.
2. A line segment extends forever in opposite directions.
3. An angle that is greater than 90 degrees and less than 180 degrees is called the obtuse angle.
4. A supplementary angle is either of two angles that together form 90□.
5. A ray is a plane that consists of two endpoints.

II Answer the following questions!

1. What does the line segment consist of?
2. What does a plane contain?
3. What does the definition of geometry include?

III Fill in the expressions: consist of, include and contain as appropriate!

1. A ray _______________ a point together with all parts on a line that lie in the same direction.
2. Geometry _______________a lot of useful information.
3. Commonly-used standard units of length ______________millimetre, centimetre, meter and kilometre.

IV Use these words to complete the following sentences:

deal, join, extend, determine

1. We ______________the angle according to its measure.
2. A line segment cannot be ___________________ in both directions.
3. Two parallel straight lines are never _________________.
4. The science _________________with geometric figures is called geometry.

Lesson 6

SURVEYING INSTRUMENTS I

Principal Surveying Instruments in Distance Measurement

Distance measurement is the basis of all surveying. Even though angles may be read precisely with elaborate equipment, the length of at least one line must be measured to supplement the angles in locating points. In plane surveying the distance between two points means the horizontal distance. If the points are at different elevations, the distance is the horizontal length between plumb lines at the points.

In surveying linear measurements are obtained by different methods. Taping and EDM are most commonly used by surveyors. Measurement of horizontal distances by taping consists of applying the known length of a graduated tape directly to a line a number of times.

The following equipment is available for linear measurements:

Chain – usually 20 m, 25 m, 30 m or 50 m long. A chain can be read direct to the nearest link (200 mm in length) every tenth link being marked by a tally.

Linen tapes (Cloth tapes) – may or may not be plastic coated, sometimes reinforced by a metallic thread. They are available in lengths of 10 m, 15 m, 20 m, 25 m or 30 m. They are usually graduated at intervals of either 5 mm or 10 mm depending on the inherent accuracy of the tape. They are used where low precision is permissible and where a steel tape might be broken, as in cross sectioning for a railroad or a highway.

Steel tapes and bands are commonly available in various lengths up to 100 m and can often be read direct to the nearest millimetre. For the highest degree of accuracy steel bands can be supported at each end on tripods on one of which is mounted a travelling microscope for reading the band against a fine line, engraved on the tripod head, exactly above the station.

For extreme precision an invar tape, made of an alloy of steel and nickel, is used. The advantage of a tape of this material is that its coefficient of thermal expansion is about one-thirtieth that of steel, and hence its length is not so seriously affected by temperature changes. However, since such a tape is expensive and must be handled very carefully to prevent kinking, invar tapes are not used for ordinary work.

Maps and plans always show horizontal distances. Consequently measurements made by chain, tape or band between stations at different altitudes must be corrected for slope.

Chaining pins or Taping pins are sometimes called the surveyor's arrows, they are used to mark tape lengths. Most taping pins are made of steel wire, sharply pointed at one end, have a round loop at the other end and are painted with alternate red and white bands. Sets of 11 pins carried on a steel ring are standard.

Hand level is a simple instrument used to keep the tape ends at equal elevations when measuring over rough terrain.

Plumb bob is a pointed metal weight suspended from a string and used to project the horizontal location of a point from one elevation to another.

Range Pole (ranging rod) is a pole either of steel or of wood marked with alternate red and white bands. The main utility of range poles is to mark alignment.

The essential equipment for chain surveying consists of a chain, tape, ranging rods, chaining pins and field book. The minimum team for a chain survey is two men, for it takes two to pull the chain taut each time it is laid down. Three men, a surveyor and two chainmen, is, however, a more convenient number.

EXERCISES AND DRILL

I Answer these questions!

1. Why is the distance measurement the basis of all surveying?
2. How do we measure the horizontal distance if the points are at different elevations?
3. Which methods of linear measurement are most commonly used by surveyors?
4. What does the essential equipment in chain surveying consist of?

II Connect the following sentences introducing them with one of the following conjunctions: ***even though, although, even if, while, whatever, wherever, whenever, no matter***

1. Angles may be read precisely with elaborate equipment. Distance measurement is the basis of all surveying.

2. The measurements made by chain, tape or band at different altitudes. They must be corrected for slope.

3. The minimum team for a chain survey is two men. Three men, a surveyor and two chainmen, is, however a more convenient number.

III Supply ***it (is), there is, there are.***

1. ____________ (to take) to pull the chain taut.
2. ____________ different methods to obtain linear measurements.
3. ____________ something wrong with this instrument.
4. ____________ too noisy here for us to study.
5. ____________ impossible to make measurements without any errors**Determiners**

Three men, a surveyor and two chainmen, is,*however*, *a more* convenient number.

IV Arrange the determiners in the proper order.

1. (two, only, more) data are needed to supply a complete information about the job.
2. (next, the, few) years will see many changes in surveying technology.
3. He has (half, just, a) tank of gasoline left.
4. The students were placed (other, every) seat for the examination.
5. He had (many, too, other) place to visit to stay there long.

Lesson 7

Surveying Instruments II

Level Readings and Angle Measurement

Level readings and angle measurements are probably more common than linear measurements in engineering surveying. The instruments used for these observations are, respectively, levels and theodolites, which have a common feature in the telescope.

The telescope

In its simplest form the telescope comprises an objective, an eye-piece and a diaphragm. The objective produces an inverted image at the diaphragm, and this is magnified by the eye-piece as shown in Fig. 1(a).

The telescope has two main functions:

1. It fixes accurately the line of sight (also called the line of collimation) from a point over the instrument station to some distant point. The line of sight is the straight line joining the centre of the objective and the intersection point of the cross hairs.

2. Providing its diaphragm has stadia lines in addition to cross hairs (see Fig. 1 (b)), it can be used to measure the distance between the two points, as in tacheometry. Then A_1 and B_1 are the staff readings given by the stadia lines A_2 and B_2, and A_3B_3 is the image of A_2B_2 magnified by the eye-piece.

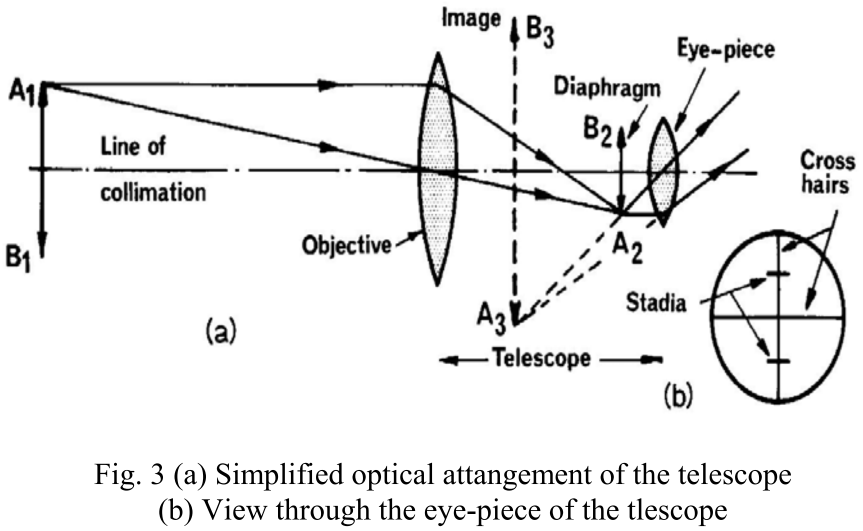

Fig. 3 (a) Simplified optical attangement of the telescope
(b) View through the eye-piece of the tlescope

The telescope is said to be correctly focused when a sharp image is obtained and there is no parallax. Parallax is tested for by moving the eye across the eye-piece. If then, the image appears to move relative to the cross hairs the two are said to exhibit parallax. There are, therefore, two focusing operations which have to performed:
a) to focus the cross hairs by screwing or sliding the eye-piece in or out; this is usually performed

while a white piece of paper is held slightly in front of the objective, and
b) to focus the target or staff by means of the focusing screw which is a knob usually mounted on the barrel of the telescope. It is at this stage that parallax is tested for and, if necessary eliminated by delicate readjustment of the focusing screw.

Construction and setting up of levels

Dumpy level

The essential feature of this instrument is that a telescope is constrained to move in a plane at 90ºto its axis of rotation. The direction of this axis is controlled by the levelling head, which comprises two so- called parallel plates separated by three, or sometimes, four footscrews. The lower parallel plate screws on to a tripod. The axis of rotation of the telescope is perpendicular to the upper parallel plate and may be made vertical, therefore, by correctly adjusting the footscrews. To set up the instrument ready for levelling, the bubble tube attached to the telescope is rotated until it is parallel to two of the footscrews, and these are turned approximately equal amounts in opposite directions until the bubble is at the centre of its run. The bubble tube is then turned through 90º and the bubble centred by the third footscrew. These two operations are repeated, in turn, until the bubble is central in both positions.

If the bubble tube is in correct adjustment the telescope will now move in a horizontal plane and the bubble will be central for every position of the telescope.

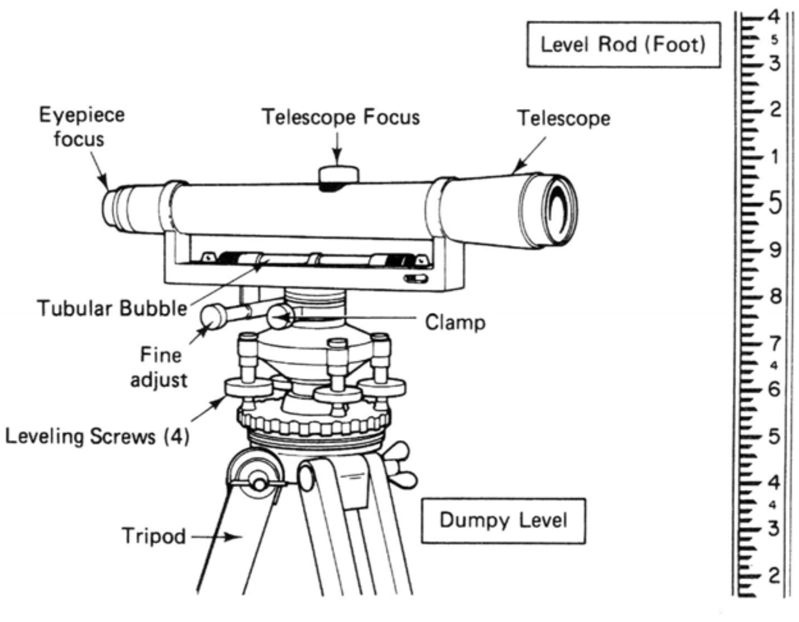

Fig. 4 Level and rod

Tilting level

The significant feature of this level is that the telescope is not constrained to move parallel to the upper parallel plate. The initial setting-up operation is simpler and quicker than for a dumpy level, and is as follows:

1. Adjust the footscrews until the circular bubble, usually situated on the upper parallel plate, is central. The instrument is then roughly level.
2. Point the telescope at the target, finally making the line of sight exactly horizontal by means of the tilting screw and the sensitive bubble mounted parallel to the telescope. In practice, the tilting screw is highly geared differential screw permitting very fine movements of the telescope. It is necessary to readjust the tilting screw for each different pointing of the telescope.

Automatic level

In both dumpy and tilting levels the line of sight lies along the optical axis of the telescope and is truly horizontal only when these instruments are correctly set up. The main feature of automatic levels is that they provide a horizontal line of sight passing through the intersection of the cross hairs even when the optical axis of the instrument is not horizontal.
It incoroporates a self-levelling feature. With most of such instruments, a bull's eye bubble is centred manually. After that, a compensator takes over, automatically levels the line of sight and keeps it level. Automatic levels have become popular of general use because of the ease and rapidity of their operation. Some are precise enough for second-order and even first-order work if a parallel-plate micrometer is attached to the telescope fron as an accessory.

EXERCISES AND DRILL

I Comprehension questions

1. What is a telescope?
2. Mention the main parts of the telescope!
3. Describe the function of the telescope!
4. When is the telescope said to be correctly focused?
5. What is the difference, in construction and method of use, between "dumpy" and "tilting" levels?
6. State in general terms the principal of "automatic level"!

II What is it?

1. 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, or target, or by means of which appropriate readings are made on some scale, such as a levelling or stadia rod is called_______________.

2. __________________ is the line extending from an instrument along which distant objects are seen, when viewed with a telescope or other sighting device.

3. A body suspended as to swing freely to and fro under the influence of
4. gravity and momentum is called______________.

5. The apparent displacement of the position of a body, with respect to a reference point or system, caused by a shift in the point of observation is called_________________.

6. A levelling instrument in which the telescope with its attached bubble tube can be levelled by a fine screw at the eye-piece end of the telescope independently of the vertical axis, thus avoiding the need for careful levelling of the instrument as a whole is called ________________.

III Form definitions from this table.

	level vial		a line		is straight and perpendicular to the vertical line.
	horizontal line		a level		telescope is rigidly attached.
	telescopes		an instrument		runs from a point to the centre of the earth.
	levelling		an object		a telescope is resting on two wyes.
	dumpy level		a tube		elevations are referred to.
(A)	horizontal plane	is	a level	which	bears a marked point whose elevation is known.
	vertical line	are	surface	whose	is perpendicular to the plumb line.
	bench mark		a process		contain an objective, a reticule, and an eye-piece.
	wye level		a plane		is made of glass and is sealed at both ends, and contains an air bubble.
	datum		instruments		determines elevations of points or differences in elevations.

Lesson 8

Electronic Distance Measurement

A major advance in surveying occurred with the development of electronic distance-measuring instruments (EDMIs). These devices determine lengths based on phase changes that occur as electromagnetic energy of known wavelength travels from one end of a line to the other end and returns.

The first EDM instrument was introduced in 1948 by Swedish physicist Erik Bergstrand. His device, called the geodimeter, resulted from attempts to improve methods for measuring the velocity of light. The instrument transmitted visible light and was capable of accurately measuring distances up to about 25 mi (40 km) at night. In 1957 a second EDM apparatus, the tellurometer, transmitted microwaves and was capable of measuring distances up to 50 mi (80 km), or more, day or night. The early EDM models had some deficiencies, but they were soon overcome by continued research and development.

Although seemingly a relatively simple procedure, precise taping is one of the most difficult and painstaking of all surveying tasks. Now EDMIs have made it possible to obtain accurate distance measurements rapidly, and easily. Given a line of sight, long or short lengths can be measured over bodies of water or terrain that is inaccessible for taping.

With modern EDM equipment, distances are automatically displayed in digital form in feet or meters, and many have built-in microcomputers that calculate both horizontal and vertical components of measured slope distances. Encoding systems within the instruments automatically supply the vertical angles needed for these calculations.

EDMIs are now being incorporated with theodolites having automatic angle readout capabilities to create so called total-station instruments. These instruments can simultaneously and automatically measure both distances and angles. When equipped with data collectors, they can record field notes electronically and transmit them to computers, plotters, and other office equipment for processing. These so-called *field-to-finish* systems are gaining world-wide acceptance and revolutionizing the practice of surveying.

There are two categories of EDMIs classified according to the wavelength of transmitted electromagnetic energy: Electro-optical instruments, which transmit light having wavelengths in the range of 0.7 to 1.2 micrometers - within or slightly beyond the visible region of the spectrum; Microwave equipment, which transmits microwaves with frequencies in the range of 3 to 35 GHz corresponding to wavelengths of about 1.0 to 8.6 millimetres.

In general EDMI measures a distance by comparing a line of unknown length of the known wavelength of modulated electromagnetic energy. The generalized procedure of measuring distance electronically is depicted in Fig. 1. An EDM device, centred by means of a plumb bob or optical plummet over station A, transmits to station B a carrier signal of electromagnetic energy on which a reference frequency has been superimposed or modulated. The signal is returned from B to the receiver, so its travel path is double the slope distance AB. In fig. 1, the modulated electromagnetic energy is represented by a series of sine waves, each having wavelength λ.

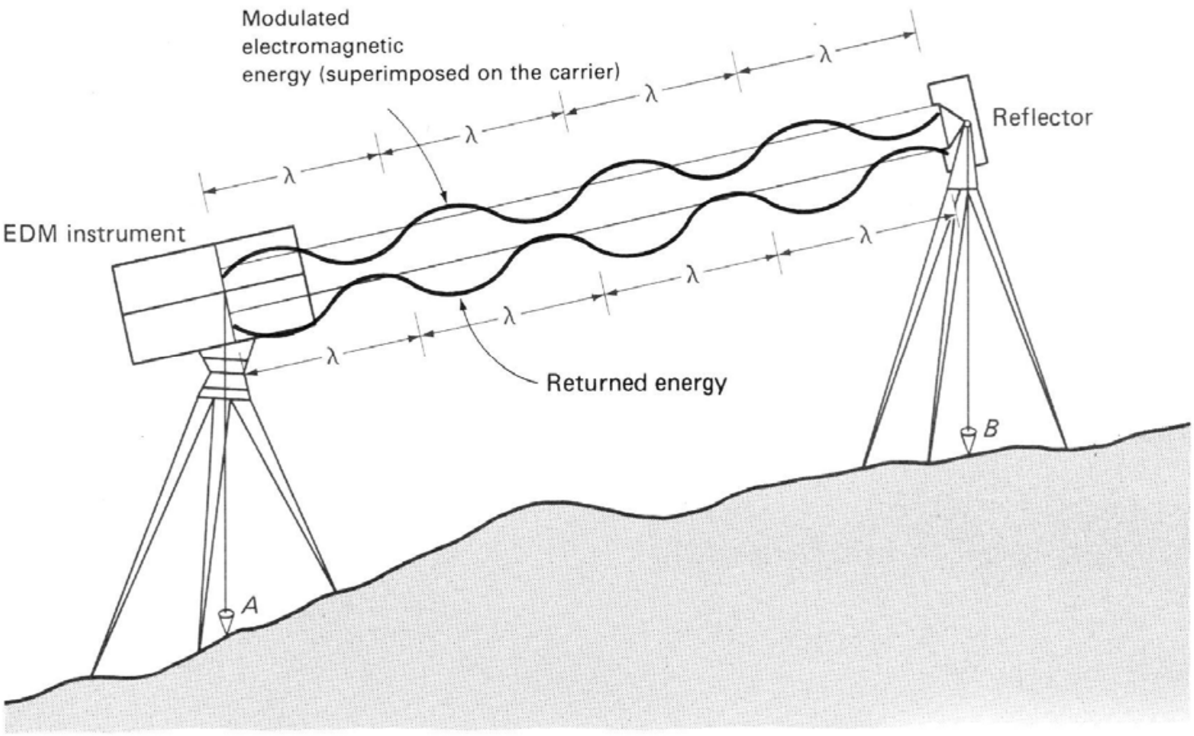

Fig. 5 Generalized EDM procedure

EXERCISES AND DRILL

I True or false?

1. EDMI is total station.
2. Taping is the easiest of all surveying methods.
3. Modern EDM equipment is fitted out to have the distances displayed automatically in a digital form.
4. All EDM's have built-in microcomputers.

II Fill in the exact prepositions!

1. Measuring _______________ a rough terrain could cause a lot of difficulties.
2. The results of measurements have to be ___________ the limits of tolerance.
3. With its modern instruments geodesy has reached far ____________ its only recently unbelievable frontiers.
4. Networks of survey monuments giving geodetic horizontal and vertical control are continually being extended __________ the country.
5. Data contained _____________ Land Information Systems are most often parcel based.
6. It is shown that things which happen randomly or by chance are governed ____ mathematical principles referred ____ as probability.

III Complete the following sentences with one of the words or phrases given below.

measuring, measured, measurements, measure

1) Electric meters are devices which ____________electric current and other electrical quantities and indicate the quality_______________.
2) Total station is used for _________________ angles and distances.
3) Distance ______________is the basis of all surveying.
4) _________________devices are very often equipped with electronic data collector.

Lesson 9

Transit and Theodolite

Transits and theodolites are perhaps the most universal surveying instruments. Although their primary use is for accurate measurement of horizontal and vertical angles, they are also commonly employed for a wide variety of other tasks such as determining horizontal and vertical distances by stadia, prolonging straight lines, and low-order differential levelling.

The main components of a transit or theodolite include a sighting telescope and two graduated circles mounted in mutually perpendicular planes. Prior to measuring angles, the "horizontal" circle is oriented in a horizontal plane, which automatically puts the other circle in a vertical plane. Horizontal and vertical angles can then be measured directly in their respective planes of reference. Level vials are the usual means of orienting the circles, although some newer theodolite and total-station instruments employ an electronic tilt-sensing mechanism.

There is no internationally accepted understanding among surveyors on the exact difference denoted by the terms *transit* and *theodolite*. As the design and manufacture of optical instruments progressed, the original very long theodolite telescope became shortened to the point that the telescope could be revolved 360 degrees about its horizontal aces. This act of turning the telescope over, called transiting the telescope, speeded up alignment work and permitted the averaging out of sighting and instrumental errors. These instruments became known as transiting theodolites, and, in time, simply as transits. Further improvements in instrument design resulted in three-screw levelling bases with optical scales, as opposed to the older design which was characterised by four-screw levelling bases, together with open-faced , silvered (later aluminium and glass) scales read with the aid of attached vernier scales. To differentiate between the old-style instruments and the newer instruments, surveyors began to call the new instruments theodolites. The vernier transits have now been largely replaced by optical scale theodolites, optical micrometer theodolites, and electronic theodolites.

Figure 5. shows a vernier transit. The lower clamp and lower tangent screw in this illustration are hidden behind the levelling head. The optical plummet shown is usually and optional accessory.

All transits and most theodolites are repeating instruments. Precise theodolites (one-second readout or smaller) have only one motion. That is, each time the theodolite is turned, the angle value changes. These theodolites are called direction instruments. Electronic theodolites are mostly direction instruments, although some manufacturers market repeating electronic theodolites. I

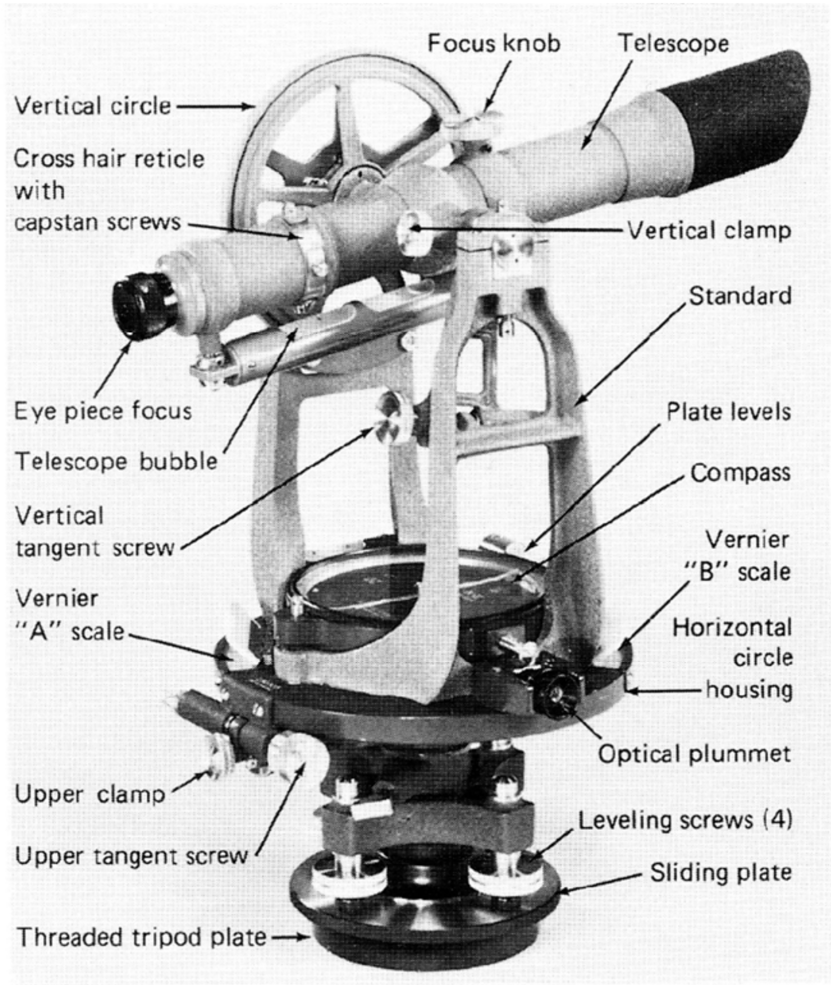

Fig. 6 Engineer's vernier transit

EXERCISES AND DRILL

I Answer these questions.

1. What is the main difference between transit and theodolite?
2. What is the theodolite used for?
3. Which are the main components of a theodolite?
4. How are readings taken with the theodolite?
5. Name the parts of an engineer's vernier transit!

II True or false:

1. Theodolite is an instrument used for measuring distances.
2. Transit and theodolite are two completely different instruments.
3. Total-stations use graduated glass scales or micrometers for the purpose of taking readings.

III Fill in the blanks with the appropriate noun forms.

1. The (maintain) _____________ of that building is the responsibility of Mr. Jones.
2. He gave a vivid (describe) _____________ of the surveying instruments used in Roman times.
3. The geodesists work all the time on the (reduce) _________ of errors of measurement.
4. We must find a (solve)___________ to the problem of obtaining more accurate results.
5. A (compare)_____________between the two systems reveals that one is much more efficient than the other.
6. The development of surveying instruments through the history indicates to their (evolve) _____________ from instruments used in astronomy.
7. In the seventh century B.C. the height of pyramids was determined by means of a (recognise) ___________of the relationship between similar triangles.
8. From the 19th century until the present the (improve) _______________ in the engineer'transit and level have been gradual.
9. The (cover)__________ of a certain area is taken into consideration in surveying.

Passive Voice

The Passive voice is very important in English. Probably quite 90 per cent. of the passive sentences spoken or written are of the type replacing the indefinite pronoun or reflexives in other languages. In this important class of passive voice sentences we have an unknown or vague active voice subject; it remains unexpressed in the passive voice. The agent with "by" is not needed.

Exp. The tangent screw *is associated* with each clamp.
It *can be used* only when the clamp is tight.

IV Turn the following sentences into passive voice:

1. Three, sometimes four footscrews separate the two parallel plates.
2. We can obtain more accurate readings by changing face.
3. If we turn the telescope in a vertical plane, it is then inverted.
4. We use the theodolite for measuring angles.
5. They say that the theodolite is more accurate than the transit.
6. Theodolite are rapidly replacing transits in USA.

V Turn the following sentences into active voice:

1. The theodolite is carefully set up at I.
2. Centring is described as positioning the instrument so that the plumb bob is exactly over the station.
3. Theodolites are considered as the most universal surveying instruments.
4. The optical reading transits are read from glass verniers views through magnifying glasses.

VI What is it? Fill in the right expression!

1. A short auxiliary scale situated along the graduated scale of an instrument, by means of which tractional parts of the smallest division of the primary scale can be measured accurately, is called _________________.

2. Placing the instrument (theodolite or level) in position and levelled, to be ready for taking measurements is called________________.

3. The axis about which the telescope of a theodolite or transit rotates when moved vertically is called ________________.

4. _________________ is a levelling instrument which has its telescope permanently attached to the levelling base, either rigidly or by a hinge that can be manipulated by a micrometer screw.

Lesson 10

The Use of Theodolite

In Traversing and Tacheometry

In all construction projects, before engineering work is commenced pegs are placed on the site to mark important centre-lines and other key points such as the corners of buildings. Such work is named setting out, and it is often performed by tapes and chains. When greater accuracy is required a theodolite may be used. Sometimes, for example when setting out curves for a road or railway, special techniques are employed. Apart from setting out, the theodolite finds most of its work in traversing and tacheometry.

Traversing

A traverse is a form of control survey that is used in a wide variety of engineering and property survey. Essentially, traverses are a series of established stations tied together by angle and distance. The angles are measured by transits or theodolites. The distances can be measured by steel tape, EDM, or even stadia. According to their form traverses can be classified as *closed* or *open*. In a closed traverse, the lines either return to the starting point, thus forming a closed polygon, as shown in Figure 1a, or they finish upon another station that has a positional accuracy equal to or greater than that of the starting point and it must have a closing reference direction.

An open traverse is particularly useful as control for preliminary and construction surveys for roads, pipelines, electricity transmission lines, and the like. These surveys may be from a few hundred meters to many kilometres in length. The distances are normally measured y using steel tapes of EDM. Each time the surrey line changes direction, a deflection angle is measured with a theodolite. The angles are measured either to the right or to the left and the direction is shown in the field notes along with the numerical values. Angles are measured at least twice to eliminate mistakes and to improve accuracy.

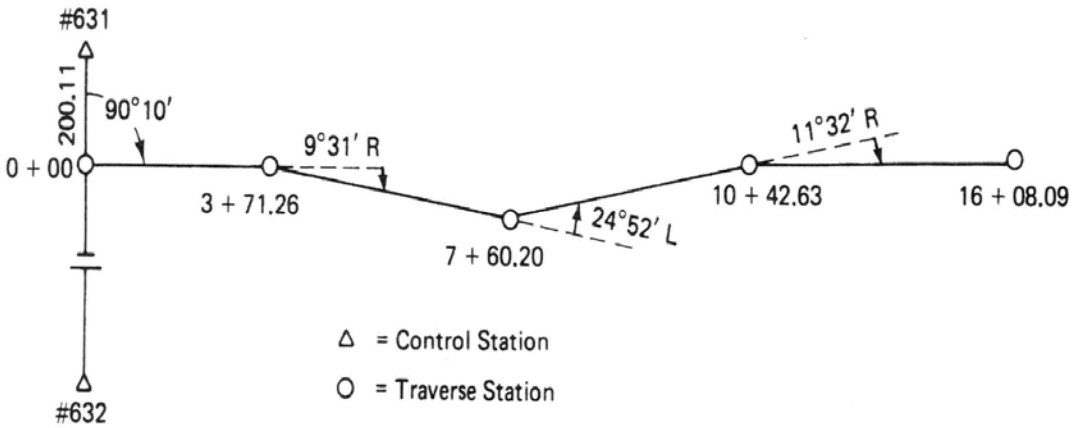

Fig. 7 Open traverse

The distances are shown in the form of stations (chainages) that are cumulative measurements referenced to the initial point of the survey. Open traverses may extend for long distances without the opportunity for checking the accuracy of the ongoing work. Accordingly, all survey measurements are carefully repeated at the time of the work, and every opportunity for checking for position and direction is utilised.

Closed traverse is one that either begins and ends at the same point or begins and ends at points whose positions have been previously determined. In both cases, the angles can be closed geometrically and the position closure can be determined mathematically. A closed traverse that begins and ends at the same point is called a loop traverse. In this case, the distances are measured from one station to the next and verified, a steel tape or EDM being used. The interior angle is measured at each station, each angle is measured at least twice.

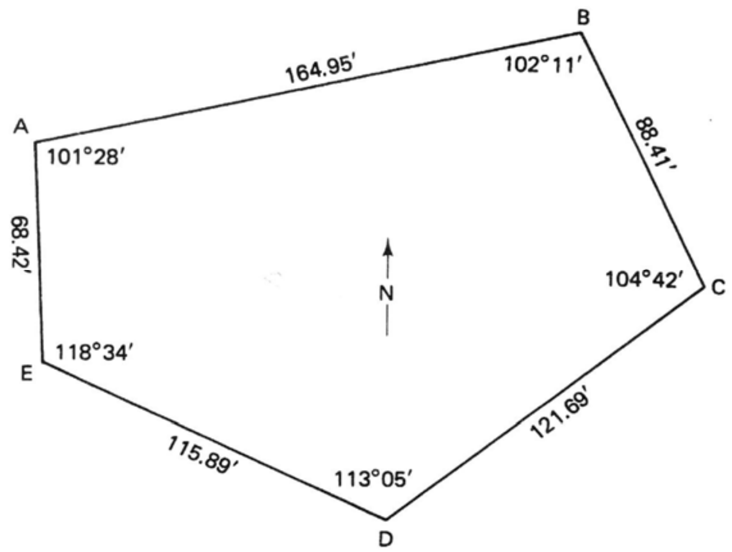

Fig. 8 – Closed traverse (loop)

Tacheometry

Tacheometry (*stadia* is a more common term in the USA) is a surveying method used to quickly determine the horizontal distance to, and elevation of, a point. These measurements are obtained by sighting through a telescope equipped with two or more horizontal cross hairs at known spacing. The apparent intercepted length between the top and bottom hairs is read on a graduated rod held vertically at the desired point. The distance from telescope to rod is found by proportional relationship in similar triangles.

EXERCISES AND DRILL

I Answer these questions:

1. Which areas of surveying is the theodolite used in?
2. What is traversing?
3. What is the difference between closed and open traverse?
4. What kind of surveying method is tacheometry?

Let's practice: description of method

exp. These measurements are obtained by sighting through a telescope. (How are these measurements obtained?)

If we want to obtain these measurements, we should sight through a telescope.

II Make sentences according to the example above.

1. Setting out is often performed by taping.
2. We obtain the lengths of the consecutive lines in a traverse by determining them from field measurements.
3. The telescope can be turned by freeing the upper clamp.
4. We can get horizontal distances and differences in elevation by using rapid indirect methods which are based on the optical geometry of the instruments employed.

III Rephrasing: Replace the underlined words with expression from the text which have a similar meaning.

1. Before <u>starting</u> any field work, it is necessary to determine the surveying method.

2. <u>Besides</u> theodolites and transits, levels can also be used to take stadia readings.

3. <u>Tacheometry</u> in surveying is used to denote procedures for obtaining horizontal distances and difference in elevation by rapid indirect methods.

4. The reticle in the telescope of the theodolite is <u>outfitted</u> with three horizontal cross hairs.

5. We can <u>find our position</u> by looking round for landmarks.

6. The fighter-plane can <u>interrupt</u> the enemy bombers.

Lesson 11

Accuracy and Precision

Since surveying is after all a measurement science, it is necessary to distinguish between the two terms, accuracy and precision which, if not understood, cause needless confusion. A discrepancy is the difference between two measured values of the same quantity. A small discrepancy indicates there probably are no mistakes, and random errors are small. The accuracy of a measurement is an indication of how close it is to the true value of the quantity that has been measured. In order to obtain an accurate measurement, one must have calibrated the measuring instrument by comparison with a standard. This allows for the elimination of systematic errors.

The precision of a measurement has to do with the refinement used in taking the measurement, the quality (but not necessarily the accuracy) of an instrument, the repeatability of the measurement, and the finest or least count of the measuring device. It is evaluated on the basis of discrepancy sizes. If multiple measurements are made of the same quantity and small discrepancies result, this indicates high precision. The degree of precision attainable is dependent on equipment sensitivity and observer skill.

Errors and mistakes

The value of a distance or an angle obtained by field measurements is never exactly the true value, except by chance. The measured value approaches the true value as the number and size of errors in the measurements become increasingly small. By definition an error is the difference between a measured value for a quantity and its true value. Errors result from instrumental imperfections, personal limitations and natural conditions affecting the measurements. Examples of instrumental errors are a tape that is actually longer or shorter than its indicated length, errors in the graduations of the circles of an engineer's transit and defect in adjustment of a transit or a level. Examples of personal limitations are the observer's inability to bisect a target or read a vernier exactly, inability to maintain a steady tension on the end of a tape, and failure to keep a level bubble centred at the moment at which a levelling observation is taken. Examples of natural conditions affecting a measurement are temperature changes, wind, refraction of a line of sight because of atmospheric conditions, and magnetic attraction.

Mistakes are sometimes called gross errors, but should not be classified as errors at all. They are blunders, often resulting from fatigue or the inexperience of the surveyor. Mistakes are caused by a misunderstanding of the problem, carelessness, or poor judgement. Examples of mistakes are failure to record each full tape length in taping, misreading a tape, interchanging figures, and forgetting to level an instrument before taking an observation. They are avoided by exercising care in making measurements, by checking readings, by making check measurements, and to a great extent by common sense and judgement.

It can be unconditionally stated that no measurement is exact, every measurement contains errors, the true value of a measurement is never known, and, therefore, the exact error present is always unknown. As better equipment is developed, measurements will more closely approach their true values.

EXERCISES AND DRILL

I Comprehension

1. Discuss the difference between accuracy and precision!
2. List the sources of errors in surveying. Give an examples of each!

Relative Clauses - Defining and non-defining relative clauses

exp. Example of instrumental errors is a tape that is actually longer or shorter than its standard.

Defining relative clause provide an indispensable definition of the word to which the relative clause relates. They are not separated from the antecedent by commas in writing, nor by a pause in speech. This is a basic feature of all defining relative clauses.

exp. Examples of natural conditions, which affect measurements, are temperature changes, wind, refraction of a line of sight etc.

Non-defining relative clause is enclosed by commas and can be omitted from the sentence without changing the meaning of the main clause.

II Join the following pairs of sentences and state whether the completed sentences contain defining or non-defining relative clauses.

1. Precision implies a refinement of measurement.
   It necessitates using precision instruments under ideal conditions with the best techniques and obtaining several repetitions of closely agreeing observations.

2. Errors are deviations of observations or calculations from their true values.
   The deviations are beyond the control of the one performing the operations.
3. Construction surveys are a special type of surveys.
   They are executed to locate or lay out engineering works.

4. A horizontal distance between two given points is the distance between the points.
   They are projected onto a horizontal plane.

5. A zenith angle is also an angle.
   It is measured in a vertical plane.

6. The difference in elevation between two points is the vertical distance between the two level surfaces.
   These surfaces contain the two points.

III Fill in the appropriate prepositions

1. The numbers are round off _____ any required degree of accuracy.
2. The distance ______ the river can be found by measuring the length of a line ____ one side, the angle ____ each end of this line ____ a point ____ the other side.
3. There is an increasing demand ____ maps.
4. Surveyors and engineers must know when to work ___ hundredths ____ a foot.
5. A definite precision ____field data is necessary to justify carrying out computations ____ the desired number of decimal places.
6. Taking field notes _____ all sorts of conditions is excellent preparation ____ the kind of recording and sketching expected of all engineers.

Lesson 12

Sources and Types of Errors

Errors in measurement stem from three sources and are classified accordingly.

Natural errors are caused by variations in wind, temperature, humidity, refraction, gravity and magnetic declination. For example, the length of a steel tape varies with changes in temperature.

Instrumental errors result from any imperfection in the construction or adjustment of instruments and from the movement of individual parts. For example, the graduations on a scale may not be perfectly spaced, or the scale may be warped. The effect of many instrumental errors can be reduced, or even eliminated, by adopting proper surveying procedures or applying computed corrections.

Personal errors arise principally from limitations of the human senses of sight and touch - for example, there is a small error in the measured value of a horizontal angle if the vertical cross hair in a theodolite is not aligned perfectly on target, or if the top of a rod is out of plumb when sighted.

Errors in measurement are of two types: systematic and random.

Systematic errors conform to mathematical and physical laws. Their magnitude may be constant or variable, depending on conditions. Systematic errors, also known as cumulative errors, can be computed and their effects eliminated by applying corrections.

Random errors remain after mistakes and systematic errors have been eliminated. They are caused by factors beyond the control of the observer, obey the laws of probability, and are sometimes called accidental errors.

The magnitude and algebraic signs of random errors are matters of chance. There is no absolute way to compute or eliminate them, but they can be estimated using adjustment procedures known as least squares, since they tend to partially cancel themselves in a series of measurements. For example, a person interpolating to hundredths of a foot on a tape graduated only to tenths, or reading a level rod marked in hundredths, will presumably estimate too high on some values and two low on others. Individual personal characteristics may nullify such partial compensation, however, since some people are inclined to interpolate height, other interpolate low, and many favour certain digits - for example, 7 instead of 6 or 8, 3 instead of 2 or 4, and particularly 0 instead of 9 or 1.

All field operations and office computations are governed by a constant effort to eliminate mistakes and systematic errors. Mistakes can be corrected only if discovered. Comparing several measurements of the same quantity is one of the best ways to isolate mistakes. Making common sense estimates and analysis is another.

Systematic errors can be calculated and proper corrections applied to the measurements, or a field procedure used that automatically eliminates the errors.

There are some general laws of probability to be stated with respect to the occupancy of errors.

1. Small errors occur more often than large ones; that is, they are more probable.
2. Large errors happen infrequently and are therefore less probable; for normally distributed errors, unusually large ones may be mistakes rather the random errors.
3. Positive and negative errors of the same size happen with equal frequency; that is, they are equally probable.

We have already mentioned that in physical measurement, the true value of any quantity is never known. Its most probable value can be calculated, however, if redundant measurements have been made. Redundant measurements are observations in excess of the minimum needed to determine a quantity. For a single unknown, such as a line length, that has been directly and independently measured a number of times using the same equipment and procedures, the first measurement establishes a value for the quantity and all additional observations are redundant

In more complicated problems where the observations are not made with the same instruments and procedures, or if several interrelated quantities are being determined through indirect measurements, most probable values are calculated by employing least squares methods.

Having determined the most probable value of a quantity, it is possible to calculate residuals. A residual is simply the difference between any measured value of a quantity and its most probable value. Residuals are theoretically identical to errors with the exception that residuals can be calculated whereas errors cannot because true values are never known.

EXERCISES AND DRILL

I Answer these questions.

1. What does the magnitude of systematic errors depend on?
2. What is the difference between systematic and random errors?
3. Is it possible to eliminate errors and how?
4. What are redundant measurements?
5. When do we employ the least square methods?
6. Give the definition of residuals?

Scales of degree

exp. Random errors tend to *partially* cancel themselves in a series of measurements.

II Fill in the blanks with one of the words below:

1. Surveying has become one of the ________estimated sciences.
2. In the past, field measurements for geodetic surveys consisted _______________of angles observed using ground-based theodolites, and distances measured with tapes or electronic devices.
3. Surveyors, whose work must be performed to exacting standard, should be _____ aware of the different kinds of errors.
4. Every observer knows that it is impossible to obtain a result which is _________________ correct.
5. Errors may be ___________ divided into two classes: systematical and random errors.
6. If a line of _____________ 100 feet is being measured, the reading may be booked as 101.10 feet, whereas it should be 100.10 feet.
7. Some errors are not so serious because they can be ___________wholly eliminated.

absolutely, almost, approximately, fully, highly, primarily, roughly

Lesson 13

Least Squares Adjustment

Least squares is suitable for adjusting any of the basic types of surveying and is applicable to all of the commonly employed surveying procedures, including levelling, traversing, triangulation and trilateration. In performing the least squares adjustment, the sum of weights of the measurements, times their corresponding squared residuals, is minimized. This fundamental condition, which is developed from the equation for the normal error distribution curve, provides most probable values for the adjusted quantities. Making adjustments by least squares is not new, having been done by the German mathematician Karl Gauss as early as the latter part of the eighteenth century. Until the advent of computers, however, it was only employed sparingly because of the lengthy calculations involved compares to other methods. The basic assumptions that underlie least squares theory are:

- mistakes and systematic errors have been eliminated so only random errors remain,
- the number of observations being adjusted is large,
- the frequency distribution of errors in normal.

Although these assumptions are not always met, least squares adjustment still provides the most rigorous error treatment available, and hence it has become very popular and important in modern surveying. Besides yielding most probable values for the unknowns, least square adjustment also determines precision of adjusted quantities, reveals the presence of large errors and mistakes so steps can be taken to eliminate them and makes possible the optimum design of survey procedures in the office before going into the field to take measurements.

The method of least squares is particularly well suited for adjusting indirect measurements to obtain most probable values for unknown quantities that are interrelated. One of two basic approaches can be employed: 1) the observation equation method and 2) the condition equation approach. In the first method, which is most commonly applied, "Observation equations" are written which related measured values to their residual errors and the unknowns in the problem. (Residual errors can be calculated after having determined the most probable value of a quantity. It is simply a difference between any measured value of a quantity and its most probable value. The most probable value can be calculated, however, if redundant measurements have been made). One equation is developed for each measured quantity. Redundant measurements are observations in excess of the minimum needed to determine a quantity. For a single unknown, such as a line length, that has been directly and independently measured a number of times using the same equipment and procedures, the first measurement establishes a value for the quantity and all additional observations are redundant. The most probable value in this case is simply the arithmetic mean. If redundant observations are made, the number of equations will exceed the number on unknowns, and their most probable values can be determined by least squares.

In many surveying adjustment problems, the observation equations are nonlinear and must be linearized. In addition, the least squares solution to obtain most probable values for the unknowns requires calculus.

EXERCISES AND DRILL

I True or false!

1. Least squares are geometrical figures.
2. Least squares method can be applied when mistakes and errors have been eliminated and only random errors remain.
3. Least squares adjustment determines the precision of adjusted quantities.

II What is it?

1. The determination and application of corrections to observations, for the purpose of reducing errors or removing internal inconsistencies in derived results is called ________________and may be related either to mathematical procedures or to corrections applied to instruments used in making observations.
2. A condition equation which connects interrelated unknowns by means of an observed function or a condition equation connecting the function observed and the unknown quantity whose value is sought is called _________________________.

3. ________________ is the degree of refinement in the performance of an operation or the degree of perfection in the instruments and methods used when making the measurements and relates to the quality of the operation by which a result is obtained.

4. A method of calculation using a special system of notation in symbols is called _______________.

Finite and non-finite clauses

A group of words containing a finite verb is called a finite clause (adjectival, noun and adverbial clause). Non-finite clauses contain parts of the verb which are non-finite (having no number, person and tense).

III Replace the non-finite clauses by finite!

1. This condition developed from the equation for the normal error distribution curve provides most probable values.

2. Random errors appearing in surveying are normally distributed.

3. The adjustment computations based on the theory of probability are valid only if systematic errors and mistakes have been eliminated.

4. Making adjustments having been done by the German mathematician Karl Gauss in the 18th century has not been very much employed.

5. The equipment used in surveying must also be adjusted.

6. Let's consider a line requiring two adjacent measurements having the same possible error.

Angles, Bearings and Azimuths

Determining the locations of points and orientations of lines frequently depend on measurements of angles and directions. In surveying, directions are given by bearings and azimuths.

Angles measured in surveying are classified as horizontal or vertical, depending on the plane in which they are measured. Horizontal angles are the basic measurements needed to determine bearings and azimuths. Vertical angles are used in trigonometric levelling, stadia and for reducing measured slope distances to horizontal.

Angles are most often directly measured in the field by theodolite or transit, but a compass or sextant can be used. Angles can be constructed without measurement on a plantable sheet. The sextant is a hand-held instrument that can be used to measure angles in any plane. It consists of a telescope and mirrors which enable simultaneous viewing of two points. In measuring an angle with a sextant, the apex is at the eye of the observer who sights through the telescope. Adjustments are made to the mirrors, one of which is half-silvered, until the two points being viewed coincide. In that position, the angle between them can be read from a graduated arc. Sextants have been used principally by navigators to find their positions by observing angles to the stars. Surveyors also use them to locate their hydrographic survey boat by measuring angles to control points on shore. The natural ability of humans to stand erect in spite of boat pitch and roll makes sextants ideal for these uses.

An angle can be measured indirectly by the tape method, and its value computed from the relationship of known quantities in a triangle or other simple geometric figure.

Three basic requirements determine an angle. They are the reference or starting line, direction of turning, and angular distance (value of the angle).

The value of an angle is defined by a purely arbitrary unit. The sexagesimal system used in the United States and many other countries is based on degrees, minutes and second, with the last unit further divided decimally. In Europe the grad or gon is a standard unit. Radians may be more suitable in computation, and in fact are employed in electronic computers.

The kinds of horizontal angles most commonly measured in surveying are: interior angles, angles to the right and deflection angles. Because they differ considerably, the kind used must be clearly indicated in field notes.

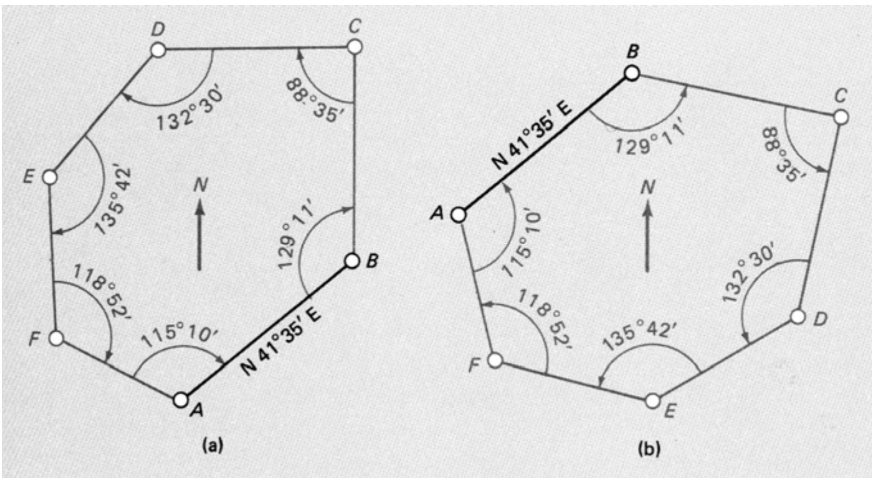

Fig. 9 Interior angles

Interior angles (Fig. 9) are on the inside of a closed polygon. Exterior angles, located outside a closed polygon, are explements of interior angles. The advantage to be gained by measuring them is their use as a check, since the sum of the interior and exterior angles at any station must equal 360°.

Interior angles can be turned clockwise (right) or counterclockwise (left). By definition, angles to the right are measured clockwise from the rear to the forward station. Angles to the left are turned counterclockwise from the rear station.

Deflection angles (Fig. 10) are measured right (clockwise, considered plus) or left (counterclockwise, considered minus) from an extension of the back line to the forward station. Deflection angles are always smaller than 180°, and the direction of turning is defined by appending an R or L to the numerical value.

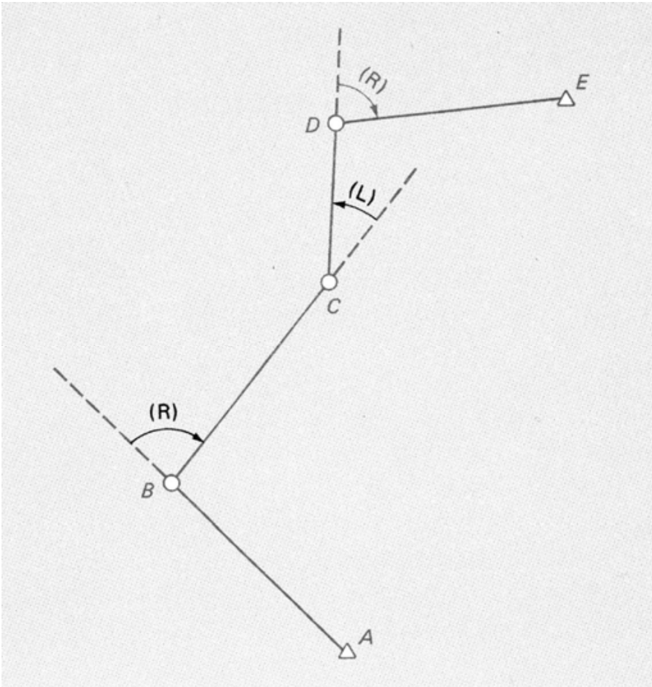

Fig. 10 Deflection angle

Direction of a line

The direction of a line is the horizontal angle between it and an arbitrarily chosen reference line called a meridian. Different meridians are used. An astronomic (sometimes called "true") meridian is the north-south reference line through the earth's geographic poles. A magnetic meridian is defined by a freely suspended magnetic needle that is influenced by the earth's magnetic field only. A magnetic pole is the centre of convergence of magnetic meridians. An assumed meridian can be established by merely assigning any arbitrary direction - for example, taking a certain street line to be true north. The directions of all other lines are then found in relation to it. Disadvantages of using an assumed meridian are the difficulty, or perhaps impossibility, of re-establishing it if the original points are lost, and its non-conformance with other surveys and maps. Surveys based on a state or other plane co-ordinate system employ grid meridian for reference. Grid north is the direction of true north for a selected central meridian. Other types of meridians are guide, central, prime and local.

Bearings

Bearings represent one system for designating the directions of lines by means of an angle and quadrant letters. The bearing angle of a line is the acute horizontal angle between a reference meridian and the line. The angle is measured from either the north or south toward the east or west to give a reading smaller than 90°. In Figure 11, all bearings in quadrant NOE are measured clockwise from the meridian. Thus, the bearing of line OA is N70°E. All bearings in quadrant SOE are counterclockwise from the meridian, so OB is S35°E. Similarly, the bearing of OC is S55°W and that of OD, N30°W.

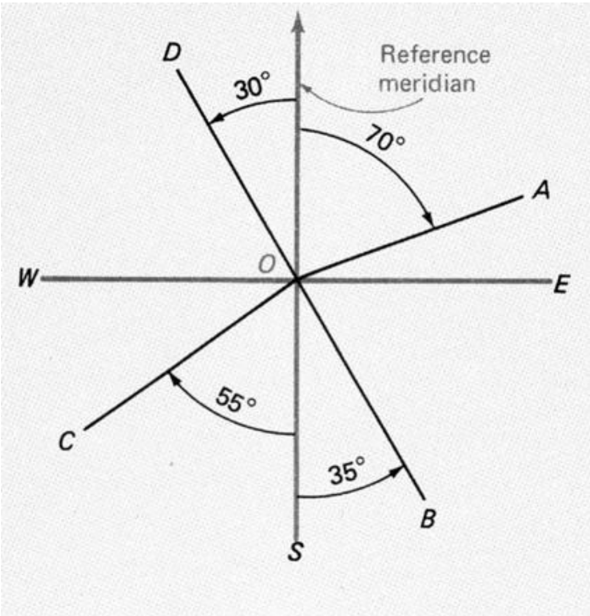

Fig. 11 Bearing angles

True bearings are measured from the local astronomic or true meridian, magnetic bearings from the local magnetic meridian, assumed bearings from any adopted meridian, and grid bearing from the appropriate grid meridian. Magnetic bearings can be obtained in the field by observing the magnetic needle of a compass, and used along with measured angles to get computed bearings.

Azimuths are angles measured clockwise from any reference meridian. In plane surveying, azimuths are generally measured from north, but astronomers, the military and the National Geodetic Survey have used south as the reference direction. Azimuths range from 0 to 360°. They may be true, magnetic, grid or assumed, depending on the reference meridian used. They may also be forward or back azimuth. Forward azimuths are converted to back azimuths, and vice versa, by adding or subtracting 180°. Azimuths can be read on the graduated circle of a transit or repeating theodolite after the instrument has been oriented properly. They are used advantageously in some topographic, control and other surveys, as well as in computations.

EXERCISES AND DRILL

I Answer these questions:

1. What does the classification of angles in surveying as horizontal or vertical depend on?
2. What do the surveyors use a sextant for?
3. Which requirements determine an angle?
4. Which are the possibilities to define the value of an angle?
5. What is the distinction between the three kind of horizontal angles?
6. Why is it necessary to know the direction of a line?
7. Give the definitions of bearings and azimuths?
8. Why are deflection angles often used in route-surveys?

II complete the following sentences correctly.

1. Bearings can be determined both ___________________ or __________________ from the specified direction, so that the bearing does not exceed 180°.
2. Angle to the right is the angle measured _____________ from the ___________to the _________station.
3. Azimuths are angles ______________________.
4. Deflection angle is the angle between the prolongation of the back line measured right or left to the forward line.
5. The measurement of angles and directions gives the location of___________ and __________lines.
6. Directions are given by______________.
7. Depending on the plane _____________ angles can be classified as_________________________.
8. Interior angles are located on_______________________of a _____________.
9. _________ angles are measured clockwise (to the right) or _______________(_________).

III Change the relative clause in these sentences to an –ing, past participle, or being + past participle clause as appropriate.

1. Angles that are measured in surveying are classified as horizontal or vertical which depends on the plan they are measured in. ____
2. Unlike an azimuth, which is always an angle measured in a definite direction from a definite half of the meridian, a bearing angle is never greater than 90°.____
3. The bearing of a line in the direction in which a survey that contains several lines is progressing is called the forward bearing.____
4. The line that is in the south-east quadrant is equal to the bearing angle.____
5. When the azimuth of a line is stated, it is understood to be that of the line that is directed from an original point to a terminal point. ____

IV Points for discussion.

Location of points, orientation of lines, and directions
Horizontal and vertical angles: interior angles, angles to the right, deflection angles
Comparison of bearings and azimuths
Lesson 15

Topographic Surveys

Topographic surveying is the process of determining the positions, on the earth's surface, of the natural and man-made features of a given locality and of determining the configuration of the terrain. The location of the features is referred to as planimetry, and the configuration of the ground is referred to as topography or hypsography. The purpose of the survey is to gather data necessary for the construction of a graphical portrayal of planimetric and topographic features. This graphical portrayal is a topographic map. Such a map shows both the horizontal distances between the features and their elevations above a given datum. On some maps the character of the vegetation is shown by means of conventional symbols.

Topographic surveying or mapping is accomplished by ground methods requiring the use of the transit or theodolite, plane table and alidade, level, hand level, tape and levelling rod in various combinations. Total station instruments are used to advantage in topographic surveying. The vast majority of topographic mapping is accomplished by aerial photogrammetric methods. In the photogrammetric methods, however, a certain amount of field completion and field editing must be done by ground methods.

The preparation of a topographic map, including necessary control surveys, is usually the first step in the planning and designing of an engineering project. Such a map is essential in the layout of an industrial plant, the location of a railway or highway, the design of an irrigation and drainage system, the development of hydroelectric power, city planning and engineering, and landscape architecture. In time of war, topographic maps are essential to persons directing military operations.

Since a topographic map is a representation, on a comparatively small plane area, of a portion of the surface of the earth, the distance between any two points shown on the map must have a known definite ratio to the distance between the corresponding two points on the ground. This ratio is known as the scale of the map. A fraction indicating a scale is referred to as the representative fraction. It gives the ratio of a unit of measurement on the map to the corresponding number of the same units on the ground. The scale to which the map is plotted depends primarily on the purpose of the map, that is, the necessary accuracy with which distances must be measured or scaled on the map. The scale of the map must be known before the field work is begun, since the field methods to be employed are determined largely by the scale to which the map is to be drawn.

Map scales are generally classified as large, medium and small.

Methods of representing topography

Topography may be represented on a map by hachures or hill shading, by contour lines, by form lines, or by tinting. Hachures are a series of short lines drawn in the direction of the slope. For a steep slope the lines are heavy and closely spaced. For a gentle slope they are fine widely spaced. Hachures are used to give a general impression of the configuration of the ground, but they do not give the actual elevations of the ground surface.

A contour line, or contour, is a line that passes through points having the same elevation. It is the line formed by the intersection of a level surface with the surface of the ground. A contour is represented in nature by the shoreline of a body of still water. The contour interval for a series of contour lines is the constant vertical distance between adjacent contour lines. Since the contour lines on a map are drawn in their true horizontal positions with respect to the ground surface, a topographic map containing contour lines shows not only the elevations of points on the ground but also the shapes of the various topographic features, such as hills, valleys, escarpments and ridges. Fig. 1 shows the classical illustration of the relationship between the configuration of the ground and the corresponding contour lines.

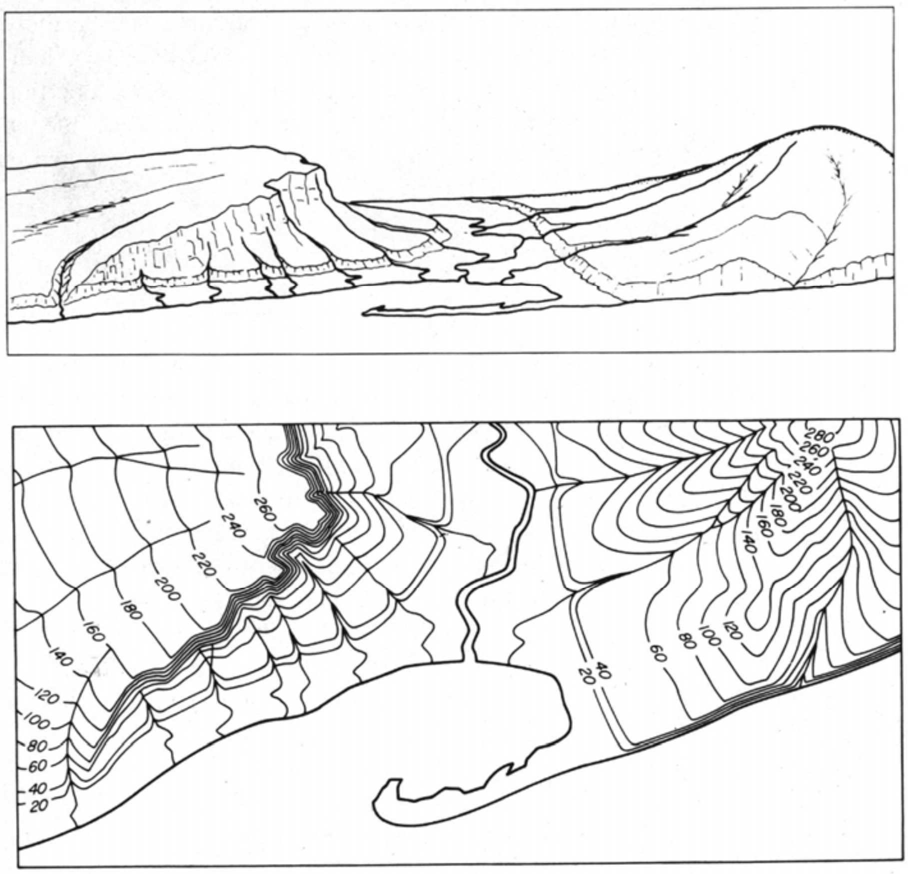

Fig. 12 Contour line representation of terrain

On maps intended for the purpose of navigation, peaks and hill tops along the coast are sometimes shown by means of form lines. Such lines resemble contours, but are not drawn with the same degree of accuracy. All points on a form line are supposed to have the same elevation, but not enough points are actually located to conform to the standard of accuracy required for contour lines.

On aeronautical charts and on maps intended for special purposes, such as those that may accompany reports on some engineering projects, elevations may be indicated by tinting. The area lying between two selected contours is coloured one tint, the area between two other contours another tint, and so on. The areas to be flooded by the construction of dams of different heights, for example, might be shown in different tints.

Among the factors that influence the field method to be employed in the compilation of a topographic map are the scale of the map, the contour interval, the type of a terrain, the nature of the project, the equipment available, the required accuracy, the type of existing control, and the extent of the area to be mapped. The area to be mapped for highway or railroad location and design takes the form of a strip. The control lines are the sides of a traverse which have been established by a preliminary survey.

To make an engineering study involving drainage, irrigation, or water impounding or to prepare an accurate map of an area having little relief, each contour line must be carefully located in its correct horizontal position on the map by following it along the ground. This is the trace contour method.

When an area of limited extent is moderately rolling and has many constant slopes, points forming a grid are located on the ground and the elevations of the grid points are determined. This is the grid method of obtaining topography.

If the area to be mapped is rather extensive, the contour lines are located by determining the elevations of well-chosen points from which the positions of points on the contours are determined by computation. This is known as controlling-point method.

EXERCISES AND DRILL

I Finish the following sentences.

1. Topographic surveys are made for the purpose of ________________________________
2. Various instruments like ______________________________are used in topographic surveying.
3. This kind of surveying is accomplished by various methods, _________________________________
4. Map scale is ____
5. Contour lines are used to ____

II Form nouns from the words below by using an appropriate suffix:

determine, curve, triangulate, reduce, connect, observe, rotate, define, locate, choose, orientate, enlarge, direct, adjust.

III Complete the following sentences by putting conjunctions in the vacant spaces to introduce adverb clauses.

Example: *When* an area of limited extent is moderately rolling and has many constant slopes, points forming a grid are located on the ground.

1. I shall do the exercises _____ I have been taught.
2. The elevations of contour lines are shown _________ they can represent a hill.
3. The ground slopes are the steepest _________ the contour interval is 20 ft.
4. The configuration of the ground and elevations of points are most commonly represented by means of contour lines __________they give a maximum amount of information.
5. _____ the work on a map is very demanding, the map itself is often treated as a work of art.

IV Finish the following sentences using the conditional clauses.

1. The contour lines are located by determining the elevation of well-chosen points if ____
2. The contour lines are sometimes called form lines if____
3. The same contours would present a ridge if __________________________________
4. Photogrammetric methods could not be used in topographic survey if ____
5. The field work in topographic survey cannot begin if____

Lesson 16

Mapping

Throughout the ages, maps have had a profound impact on human activities, and today the demand for them is perhaps greater than ever. They are of utmost importance in engineering, resource management, urban and regional planning, management of the environment, construction, conservation, geology, agriculture, and many other fields. Maps show various features - topography, property boundaries, transportation routes, soil types, vegetation, land ownership for tax purposes, and mineral and resource locations. Maps are especially important in engineering for planning project locations, designing facilities and estimating contract quantities.

Cartography, the term applied to the overall process of map production, includes construction of projections, design, drawing or compiling manuscripts, final drafting and reproduction. Digital computers have had a profound impact on all areas of surveying, and mapping is certainly no exception. Automated computer-driven plotters and Computer-Aided Drafting and Design (CADD) systems have now become commonplace in surveying and engineering offices. They are rapidly eliminating the need for manual map compilation and drafting. Nevertheless, many maps continue to be drawn manually and the same techniques provide the underlying base for operation of automated systems.

Manual map drafting

Map drafting done manually generally consists of two steps: preparing the manuscript and drafting the final map. The manuscript is usually compiled in pencil. It should be carefully prepared to locate all features and contours as accurately as possible and be complete in every detail including placement of symbols and letters. Lettering on manuscript need not be done with extreme care, for its major purpose is to ensure good overall map design and proper placement. A well-prepared manuscript goes a long way toward achieving a good quality final map.

The completed version is drafted in ink or scribed. Either process involves tracing from the manuscript. If inked, the manuscript is placed on a "light table" and features are traced on a stable-base transparent overlay material. Lettering is usually done first; then planimetric features and contours are traced.

Scribing is executed on sheets of transparent stable-base material coated with an opaque emulsion. Manuscript lines are transferred to the coating in a laboratory process. Special scribing tools are used to vary line weights and make standard symbols. Lines representing features and contours are prepared by cutting and scraping to remove the coating. Scribing is generally easier and faster than inking.

Overlay drafting to update changed topographic conditions and produce an accurate composite map is now practical and economical. The process of preparing a pencil manuscript can be divided into four parts: plotting the control; plotting the details, drawing the topography and special data; finishing the map, including labelling and lettering.

Standard symbols are used to represent special topographic features, thereby making it possible to show many details on a single sheet. Fig. 1 gives a few of the hundreds of symbols employed on topographic maps. Before symbols are place on a map, such things as building, roads and boundary lines are plotted and inked. The symbols are then drawn, or cut from standard "stickup" sheets with an adhesive on the back, and pasted on the map. A fully detailed map with colouring and shading is a work of art.

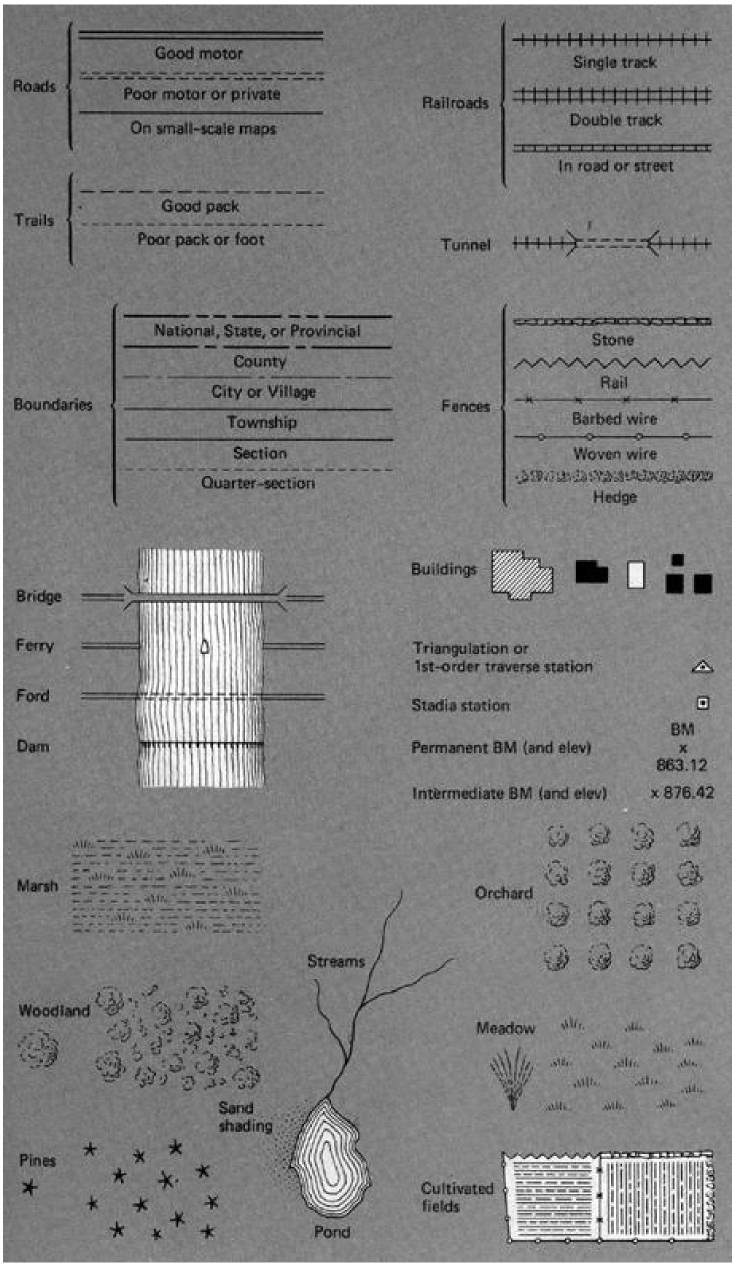

Fig. 13 Topographic symbols

Automated mapping and computer-aided drafting

Numerous computerised systems have been developed to draw maps automatically. The major advantage of these devices is greater speed in completing projects. Secondary benefits include reduction or elimination of errors, increased accuracy and preparation of a consistently more uniform final product. Moreover, all data can be stored in a data bank with different numerical codes for the various kinds of features, and recalled later for plotting in total, or parts for special-purpose maps.

The required input to a computer for an automated mapping system includes control data, topographic detail information, map scale and contour interval. Appropriate programs direct the computer to solve for the positions of points using the survey data and to plot contours and other features.

Interactive drafting (CADD) systems include an interfaced computer, CRT screen and automated drafting machine are extremely versatile. They enable operators to design and draw maps and diagrams using a computer. The operator can examine the visual map display on a screen as it is being compiled, and then make any additions, deletions, or changes as needed.

Modern multipurpose Land Information Systems (LISs), Geography Information Systems (GISs) require enormous quantities of position-related land data. From this information, maps and other special-purpose graphic displays can be made and analysed.

EXERCISES AND DRILL

I Questions for discussion.

1. Make a short description of the influence computer technology has made in mapping.
2. Explain why is a fully detailed map with colouring and shading a work of art.
3. What is the difference between the terms *cartography* and *mapping?*

II Make sentences of your own with the following compounds.

map drafting, map scale, transparent material, planimeric features, completed version, final map

III Combine each word from A with a word from B to form a compound. Explain the meaning of the newly formed compound.

A		**B**
medium		features
man-made		survey
housing		alidade
topographic		method
cultural	scale	
aerial		design
large		map
landscape		
ground		
small		
natural		
stadia		
large-scale		
plane-table		

IV Reading exercise

Man has only limited abilities to observe directly those phenomena that interest him. Some things are very tiny and we must use complex optical and electronic means (a microscope, for example) to enlarge them so as to understand their configuration and structural relationships. At the other end of the continuum some things are so large that we must somehow reduce them for the same purposes. Cartography is a technique fundamentally concerned with reducing the spatial characteristics of large areas – a portion of the earth, the moon, or even the whole earth – to a form that makes them observable. The map allows man to extend his normal range of vision, so to speak, and makes it possible for him to see the broader spatial relations that exist over large areas.

A map is much more than a mere reduction, however. If well made, it is a carefully designed instrument for recording, calculating, displaying, analysing and, in general, understanding the interrelation of things in their spatial relationship. Nevertheless, its most fundamental function is to bring things into view.

Lesson 17

Control Survey

Control surveys establish precise horizontal and vertical positions of reference monuments. These serve as the basis for originating or checking subordinate surveys for projects such as topographic and hydrographic mapping, property boundary delineation, and route and construction planning, design and layout. They are also essential as a reference framework for giving locations of data entered in Land Information Systems (LISs) and Geographic Information Systems (GISs).

There are two general types of control surveys: horizontal and vertical. Horizontal surveys over large areas generally establish geodetic latitudes and longitudes of stations. From these values, plane rectangular coordinates, usually in a state plane or universal transverse Mercator (UTM) coordinate system can be computed. On control surveys of smaller areas, plane rectangular coordinates may be determined directly without obtaining geodetic latitudes and longitudes.

To explain geodetic latitude and longitude, it is necessary to define the ellipsoid, also called a spheroid, which is a mathematical surface obtained by revolving an ellipse about the earth's polar axis. The ellipse dimensions are selected to give a good fit of the ellipsoid to the geoid over a large area. The geoid is the earth's mean sea level surface, and it is everywhere perpendicular to the direction of gravity. Because of variations in the earth's mass distribution, the geoid has an irregular shape. Geodetic latitude is the angle, in the meridian plane containing A, between the equatorial plane and the normal to the ellipsoid at A. Geodetic longitude is the angle, in the equatorial plane, between the planes of Greenwich meridian and the meridian through A. Precise latitudes and longitudes that accurately specify the relative positions of widely spaced points are determined by using geodetic field and computational techniques.

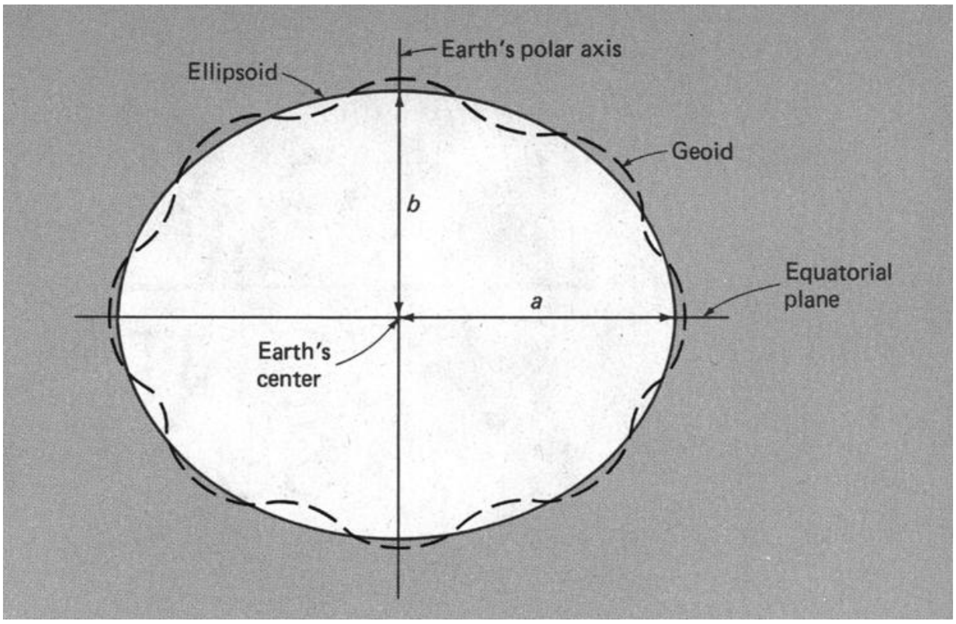

Figure 14. Ellipsoid and geoid

Field procedures used in horizontal-control surveys have traditionally been triangulation, precise traversing, trilateration and combinations of these basic methods. In addition, astronomical observations have been made to determine azimuths, latitudes and longitudes. Rigorous photogrammetric techniques have also been used to densify control in limited areas, and recently satellite and inertial systems have been employed. Global Positioning Systems (GPSs) are currently gaining widespread use for control surveying because of several advantages, an important one being their extremely high-accuracy capabilities. Terrain in the area, project requirements, available equipment and relative economy normally dictate the procedure selected.

Vertical control surveys establish elevations for a network of monuments called bench marks. Depending on accuracy requirements, vertical-control surveys may be run by barometric, trigonometric or differential levelling. Satellite and inertial systems are now also used to establish vertical control. The most accurate and widely applied method is precise differential levelling. Precise levelling is very tedious and requires extreme care. Field personnel must heed minute details to minimize systematic errors which are always present.

Horizontal and vertical datums consist of a network of control monuments and bench marks whose horizontal positions and elevations have been determined by precise geodetic control surveys. These monuments serve as reference points for originating subordinate surveys of all types.

To obtain maximum benefit from control surveys, horizontal stations and bench marks are placed in locations favourable to their subsequent use, and adequate descriptions provided. They should be permanently monumented to ensure recovery by future potential users.

The required accuracy for a control survey depends primarily on its purpose. Some major factors that affect accuracy are type and condition of equipment used, field procedures adopted and capabilities of available personnel. Usually three distinct orders of accuracy are established by standards: first order, second order and third order.

EXERCISES AND DRILL

I Answer the following questions.

1. Describe the terms geodetic latitude and geodetic longitude!
2. What different filed methods are used in horizontal-control surveying?
3. Which factors influence the choice of field method to use?
4. Explain why it is important to permanently monument and adequately describe control station.

II Fill in the the right expression.

1. The angle that the normal to the ellipsoid at a point makes with the equatorial plane of the ellipsoid is called_______________________.
2. Any quantity or set of such quantities that may serve as a referent or basis for calculation of other quantities is called_______________________.
3. __________________is the equipotential surface of the Earth's gravity field which best fits, in the least squares sense, mean sea level.
4. The angle between the plane of the local geodetic meridian and the plane of an initial, arbitrarily chosen, geodetic meridian is called _____________________.
5. __________________ is a relatively permanent, natural or artificial, material object bearing a marked point whose elevation above or below an adopted surface (datum) is known.

Lesson 18

State Plane Co-ordinates

Most surveys of small areas are based on the assumption that the earth's surface is a plane.

However, for large areas it is necessary to consider earth curvature. This is done by computing the horizontal positions of widely spaced stations in terms of geodetic latitudes and longitudes. Unfortunately, the calculation necessary to determine geodetic positions from survey measurements and get distances and azimuths from them are lengthy. Practising surveyors often are not familiar with this procedure. Clearly, a system for specifying positions of geodetic stations using plane rectangular co-ordinates is desirable, since it allows computations to be made using relatively simple co-ordinate geometry formulas.

A state plane co-ordinate system provides a common datum of reference for horizontal control of all surveys in a large area, just as mean sea level furnishes a single datum for vertical control. It eliminates having individual surveys based on different assumed co-ordinates, unrelated to those used in other adjacent work. At present, state plane co-ordinates are widely used in all types of surveys, including those for photogrammetric mapping, highway construction projects and property boundary delineation.

Projections used in State Plane Co-ordinate Systems

The earth's curved or mean sea level surface closely approximates an ellipsoid (derived by mathematically revolving an ellipse about the earth's polar axis). To convert geodetic positions of a portion of the earth's surface to plane rectangular co-ordinates, points are projected mathematically from the ellipsoid to some imaginary developable surface - a surface that can conceptually be developed or "unrolled and laid out flat" without distortion of shape or size. A rectangular grid can be superimposed on the developed plane surface and the positions of points in the plane specified with respect to X an Y grid axes. A plane grid developed using this mathematical process is called a map projection.

Two basic projections are used in state plane co-ordinate systems: the Lambert conformal conic projection and the transverse Mercator projection. The Lambert projection utilises an imaginary cone, and the Mercator a fictious cylinder, as their developable surfaces. The term conformal in Lambert projection means true angular relationships are retained around all points. Scale on a Lambert projection varies from north to south but not from east or west. It is therefore ideal for extending great distances in an east-west direction. The transverse Mercator projection is also a conformal projection based on an imaginary secant cylinder as its developable surface. Scale on this projection varies in an east-west direction, but not from north to south.

Determining state plane co-ordinates of new stations is a problem routinely solved by local surveyors. Normally it requires only that traverses (or triangulation and trilateration) start and end on existing stations having known state plane co-ordinates, and from which known grid azimuth lines have been established. Generally, these data are available for immediate use, but if not they can be calculated.

It is important to note that if a survey begins with a given grid azimuth and ties into another, all intermediate lines are automatically grid azimuths. Thus, corrections for convergence of meridians are not necessary when the state plane co-ordinate system is used throughout the survey.

The universal transverse Mercator (UTM) system is another important projection. Originally developed by the military primarily for artillery use, it provides world-wide coverage from 80°S latitude, through the equator to 84°N latitude. Each zone has 6° longitudinal width. Thus, 60 zones are required to encircle the globe. UTM zones are numbered easterly from 1 through 60, beginning at the longitude 180°.

The Lambert conformal conic and transverse Mercator map projections are designed to cover areas extensive in east-west or north-south directions, respectively. These systems do not, however, conveniently cover circular areas or long strips of the earth that are skewed to the meridian. Two other systems, the horizon stereographic and oblique Mercator projections, satisfy these problems.

EXERCISES AND DRILL

I Points for discussion.

1. Discuss the advantages of placing surveys on state plane co-ordinate systems!
2. Name two basic projections used in state plane co-ordinate systems. What are their fundamental differences?
3. What zone widths are used in the UTM system?

II Finish the following sentences.

1. A state plane co-ordinate system is necessary because________________________________
2. Geodetic positions of the Earth's surface are converted to plane rectangular co-ordinates by ____
3. Two basic projections used in state plane co-ordinate system are _____________________________________
4. The convergence of meridian is____

III Put the following sentences into Passive.

1. State plan co-ordinate system provides a common datum of reference for horizontal control of all survey in a large area. ____
2. We use two basic projections in state plane co-ordinate system.
3. Military developed Universal Transverse Mercator system originally for artillery use. ____
4. Local surveyors solve the problem of determining state plane co-ordinates of new stations. ____
5. Control survey establishes reference points and reference lines for preliminary and construction surveys.____
6. We use preliminary surveys to collect measurements showing the location of natural features.____
7. We define engineering surveying as those activities that we need in planning and execution of surveys for location, design, construction, maintenance, and operation of civil and other engineering projects. ____

Lesson 19

Boundary Surveys

The oldest types of surveys in recorded history were land surveys which date back to about 1400 B.C., when plots of ground were subdivided in Egypt for taxation purposes. They still comprise one of the main areas of surveying practice.

From Biblical times when the death penalty was assessed for destroying corners and through the years to the present, trees and other natural objects, or stakes driven into the ground have been used to identify and parcel corners.

As property increased in value and owners disputed rights to land, the importance of more accurate surveys, permanent monuments, and written records was obvious. Land titles now are transferred by written documents called deeds (grant, quitclaim, agreement, or warranty) which contain a description of the property. The various methods of description include a) metes and bounds, b) block and lot number, c) co-ordinate values for each corner, and d) township, section and smaller subdivisions.

Activities involved in the practice of land surveying can be classified into three categories: 1) original surveys to subdivide the remaining unsurveyed public lands, 2) retracement surveys to recover and monument or mark boundary lines that were previously surveyed and 3) subdivision surveys to establish new smaller parcels of land within lands already surveyed.

Modern-day land surveyors are confronted with a multitude of problems created over the past two centuries, under different technology and legal systems that now require professional solutions. These include defective compass and chain surveys, incompatible descriptions and plats of common lines for adjacent tracts, lost or obliterated corners and reference marks, discordant testimony by local residents, and a tremendous number of legal decisions on cases involving property boundaries.

Property description

Property descriptions are written by surveyors and lawyers. A single mistake in transcribing a numerical value or one incorrect or misplaced word or punctuation mark, may result in litigation for more than a generation, since the intentions of grantor (person selling property) and grantee (person buying property) may then be unclear.

Description of land in a deed should always contain the following information in addition to the recital:

1. Point of beginning which must be identifiable, permanent, well referenced and one of the property corners. Co-ordinates, preferably state plane, should be given if known or computable.

2. Definite corners that are clearly defined points with co-ordinates if possible.

3. Lengths and direction of the property sides and direction by angles, true bearings or azimuths must be stated to permit computation of any misclosure error.

4. Names of adjoining property owner are helpful to show the intent of a deed in case an error in the description leaves a gap or creates an overlap.

5. Areas are normally given as an aid in valuation and identification of a piece of property. Areas of rural land are given in acres or hectares and those of city lots in square feet or square meters. Because of differences in measurements, and depending on the adjustment method used for a traverse (compass, transit, least squares etc.), one surveyor's calculated area, angles and distances may differ slightly from another's.

Two examples of old descriptions are given below:

Beginning at an apple tree at about 5 minutes walk from Trefethence Landing thence easterly to an apple tree, thence southerly to a rock, thence westerly to an apple tree, thence northerly to the point of beginning.

With numerous apple trees and an abundance of rocks in the area, the dilemma of a surveyor trying to retrace the boundaries many years later is obvious. The second, a more typical old description of a city lot showing lack of comparable precision in angles and distances, follows:

Beginning at a point on the west side of Beech Street marked by a brass plug set in a concrete monument located one hundred twelve tenths feet southernly from a city monument NO. 27 at the intersection of Beech Street and West Avenue; thence along the west line of Beech Street S 15°14'30"E fifty feet to a brass plug in a concrete monument; thence at right angles to Beech Street S73°45'30"W one hundred fifty feet to an iron pin; thence at right angles N15°14'30"W parallel to Beech Street fifty feet to an iron pin; thence at right angles N74°45'30"E one hundred fifty to place of beginning; bounded on the north by Norton, on the east by Beech Street, on the south by Stearn, and on the west by Weston.

In subdivisions and in large cities it is more convenient to identify individual lots by block and lot number, by tract and lot number, or by subdivision name and lot number.

Exp. Lot 34 of Tract 1231 as per map recorded in book 232, pages 23 and 24 of maps, in the office of the county recorder of Los Angeles

Map books in the city or county recorder's office give the location and dimensions of all the blocks and lots. It is now standard practice to require subdividers to file a map with the proper pertinent information such as the dedication of streets. It is evident that if the boundary lines of a tract are in doubt, the individual lot lines must also be questioned.

Regarding the field work, the first task in boundary surveys is to locate all property corners. Here a most valuable piece of equipment to a land surveyor -shovel - frequently comes into use along with a magnetic locator.

In many cases one or more lines must be run from control points some distance away to check or establish the location of a corner. If control monuments are available with a known direction and co-ordinates on a state or local system (Fig. 155), occupying one of them, orienting the theodolite or transit, and running a traverse to a property corner will provide directions and co-ordinates for a boundary survey. A check is secured by closing the traverse back on the starting station or on a second nearby monument.

Generally, a closed traverse is run around the property, with all corners being occupied if possible. Hence, trees, shrubbery, hedges, and other obstacles may necessitate a traverse inside or outside the property.

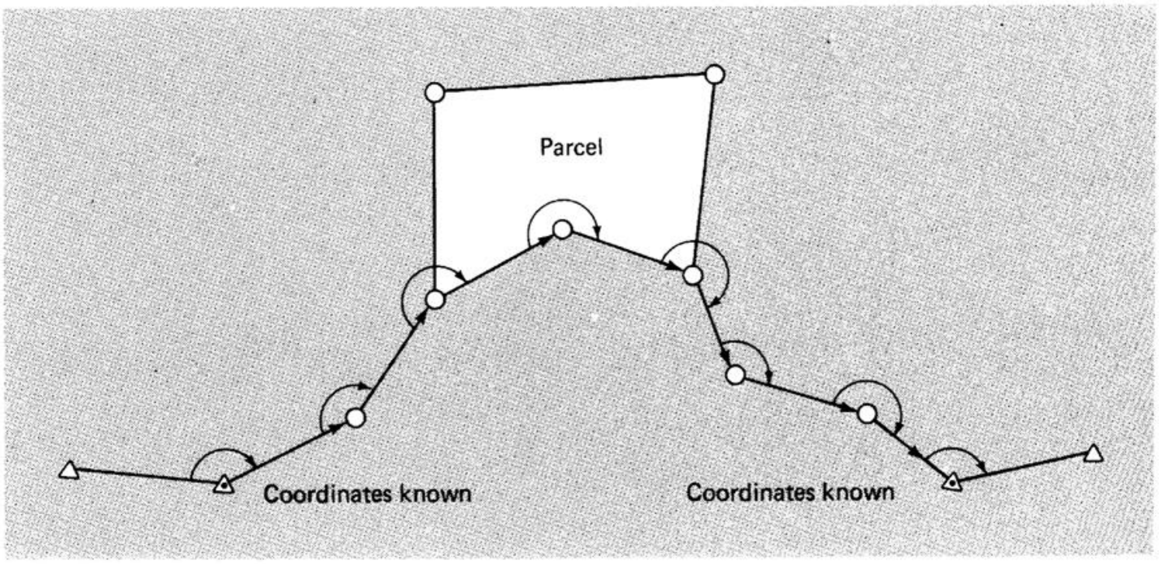

Fig. 15 Transfer of co-ordinates to a parcel by traverse

Measurements made with EDMI or standardised tape corrected for temperature and tension may not agree with distances on record or those between the marks. This situation provides a real test for surveyors. Perhaps the tape has different length from that employed on the original survey; the marks may have been disturbed or are the wrong ones; monument may not check with others in the vicinity believed or known to be correct; and perhaps several previous surveys agree with each other.

A surveyor's responsibility in a retracement survey is to relocate or establish boundary markers in the exact position where they were originally set. If part of surveyed area might be subject to claims, such as possession by other persons, the finding must be specifically noted on the surveyor's map.

Surveyors are playing a major role in the development and implementation of modern Land Information System, and this activity will continue in the future. The computerised data banks contain information or attributes about the land including its ownership, zoning, flood plain extent if any, land use, soil types, existence of mineral and water resources, and much more. The information is available for rapid retrieval and is invaluable to surveyors, government offices, lawyers, developers, planners, environmentalists and others.

Boundary surveyors are fundamental to Land Information Systems , since knowledge about the land is meaningless unless its position on earth is specified. In most modern Land Information Systems being developed, positional data are established by associating attributes about the land with individual lots or tracts of ownership. These are referred to as parcel-based Land Information Systems.

The most fundamental information associated with each individual parcel in a Land Information System is its legal description. This gives the unique location on the earth of the parcel, and thus provides the positional information needed to support the system. Legal descriptions are written instruments, based on measurements, and prepared to exacting standards and specifications. Thus, the land surveyor's role in modern Land Information System is an important one.

EXERCISES AND DRILL

I Points for discussion.

1. land-survey – the oldest type of surveys
2. importance of accurate surveys, permanent monuments and written records
3. land titles – transfer – description of property
    a) mete and bound
    b) lot number
    c) co-ordinate value for each corner
    d) township, section
4. land-surveying classification
5. problems of modern-day land surveyor
6. boundary surveyors – LIS

II Put the verbs in brackets into the correct tense.

Surveying _____(be) a profession with a very long history. Since the beginning of property ownership, boundary markers __________(require) to differentiate one property from another. Historical records dating almost 3000 years B.C. ____________(show) evidence of surveyor in China, India, Babylon, and Egypt. The Egyptian surveyor, called harpedonapata (rope-stretcher) __________(be) in constant demand as the Nile river ____________(flood) more or less continuously, destroying boundary markers in those fertile farming lands. These surveyors __________(use) ropes with knots tied at set graduations to measure distances.
It ________(presume) that the great pyramids __________(lay out) with knotted ropes, levels and various forms of water-trough levels for the foundation layout. These Egyptian surveying techniques __________(be) empirical solutions that ________(be) field-proven. It ____________(remain) for the Greeks to provide the mathematical reasoning and proofs to explain why the filed techniques _____________(work). Pythagoras ______(be) one of many famous Greek mathematicians; he and his school (about 550 B.C.) ______________(develop) theories regarding geometry and numbers. They ________(be) also among the first to deduce that the earth _________(be) spherical by noting the shape of the shadow of the earth which ___________(cast) on the moon. The term "geometry" is Greek for "earth measurement", clearly showing the relationship between mathematics and surveying. In fact, the history of surveying ___________(related) to the history of mathematics and astronomy.

III Express differently using a relative pronoun.

1. Modern-day land surveyors are confronted with multitude of problems. They require professional solutions.____
2. The first aim of the property survey is the adequate location and recording of all street lines. It constitutes the boundaries of the public's property.___________________________________
3. Some states provide for registration of property titles under rigid rules. It is necessary to remedy difficulties rising from inaccurate description and disputed boundary claims.
    ____
4. Measurements made with a DEMI or standardised tape corrected for temperature and tension may not agree with distances on record or those between the marks. This situation proves a real test for surveyors.____
5. All measurements should be made with precision. The precision should be suited to the specifications and land values. ____

Lesson 20

Construction Surveys

Construction is one of the largest industries all over the world, so surveying, as the basis for it, is extremely important. It is estimated that 60% of all hours spent in surveying are on location-type work giving line and grade.

An accurate topographic survey and site map are the first requirements in designing streets, sewer and water lines and structures. Surveyors then lay out and position these facilities according to the design plan. A final "as -built" map, incorporating any modifications made to the design plans, is prepared during and after construction, and filed. Such maps are extremely important, especially where underground utilities are involved, to assure they can be located quickly if trouble develops and will not be disturbed by later improvements.

, involves making the fundamental measurements of horizontal distances, horizontal and vertical angles, and differences in elevation using basic equipment and methods. Layout of stakes for line and grade to guide construction operations has traditionally been accomplished using the surveyor's standard equipment - levels, theodolites, tapes and EDMIs. Although these instruments are still widely employed, recent advances in modern technology have produced some truly innovative equipment and procedures that have improved, simplified and greatly increased the speed at which construction stakes can be set. New devices include visible laser beam instruments and total-station instruments that can be operated in a "tracking mode".

A stake is a piece of wood, sharpened at one end for driving into the ground. The length of the stake varies with the hardness of the ground and with the practices of different people or organizations. A hub is also a stake, usually made of wood and of varying length. It needs to be driven in firm almost to its full length and a stake (or a lath) can be driven alongside for identification, information and flagging purposes.

Staking out a building

The first task in staking out a building is to locate it properly on the correct lot by making measurements from the property lines. Most cities have an ordinance establishing setback lines from the street and between houses to improve appearance and provide fire protection.

Stakes may be set initially at the exact building corners as a visual check on positioning of the structure, but obviously such points are lost immediately when excavation is begun on the footings. A set of batter boards and reference stakes is therefore erected near each corner but out of the way of construction. The boards are nailed above the footing base, or at first-floor elevation. Corner stakes and batter-board points for rectangular buildings are checked by measuring the diagonals for comparison with each other, and their computed values. Nails are driven into the batter-board tops so that strings stretched tightly between them define the outside wall or form line of the guiding. The boards give line and grade.

Staking out a building can be a time-consuming and lengthy process if the surveyor does not give sufficient forethought to the basic control points required and the best method to establish them.

Other construction surveys are staking out a highway, a pipeline, but also causeways, bridges and offshore oil platforms. For the last three surveys it is often necessary to perform hydrographic surveys. These types of projects require special procedures to solve the problem of establishing points and depths where it is impossible to hold a rod or reflector. Triangulation, trilateration, EDMIs and sonar mapping devices are used to plot dredging cross-sections for underwater trenching and pipe laying. Today more pipelines are crossing wider rivers than ever before. Mammoth pipeline projects now in progress to transport crude oil, natural gas and water have introduced numerous new problems and solutions. Permafrost, extremely low temperatures and the need to provide animal crossings are examples of special problems.

Large earthwork projects such as dams and levees require widespread permanent control for quick setups and frequent replacement of slope stakes, all of which map disappear under fill in one day. Fixed signal for elevation and alignment painted or mounted on canyon walls or hillsides can mark important reference lines. Failures of some large structures, such as Teton Dam, demonstrate the need for periodically monitoring them so any necessary remedial work can be done.

Underground surveys in tunnels and mines necessitate transferring line and elevations from the ground above, often dawn the shafts. Direction of lines in mine tunnels can be most conveniently established using north-seeking gyros. In another, and still practised, method, two heavy plumb bobs hung on wires from opposite sides of the surface opening can be aligned by theodolite there and in the tunnel. A theodolite or laser is wiggled in on the short line defined by the two plumb-bob wires, a station mark set above the instrument, and the line extended. Later set-ups are made beneath spades (surveying nails with hooks) anchored in the roof. Elevations are brought down by taping or other means. Bench marks and instrument station are set on the roof, out of the way of equipment.

Surveys are run at intervals on all large jobs to check progress for periodic payment to the contractor. And finally, an as-built survey is made to determine compliance with plans, note changes and make terminal contract payment.

EXERCISES AND DRILL

I Answer the following questions.

1. What does construction surveying involve?
2. What does it mean to stake out a building?
3. Why do we say that surveyors are there at the beginning and at the end of a construction operation?

II Express the purpose in the following sentences by using infinitive with to, where possible.

1. Site maps are extremely important where underground utilities are involved so that they can be quickly located.____
2. Before any construction work starts, the surveyors need to stake out a building first, so that they can locate it property on the correct lot.____
3. Surveys are run at intervals on all large jobs so that the progress for periodic payment to the contractor can be checked.____
4. Nails are driven into the batter-board tops so that strings stretched tightly between them define the outside wall. ____
5. A knowledge of construction technique is required so that it can ensure optimal layout for both line and grade transfer and construction scheduling.
6. When the decision is made to proceed with the highway construction, the surveyor goes back to the field so that he may begin the stakeout.

   ____

III Fill in the missing words. Select the appropriate word from the list below. Some of the words

given may occur several times.

weights, curvature, survey, flat, gravity, natural, chainmen, plane, measuring, elevations, larger, perpendicular, distances, plumb bob, geodetic, accuracy, recording.

Before any civil engineering project can be designed, a __________ of the site must be made. Surveying means _________________and __________ by means of maps the earth's surface with the greatest degree of ____________ possible. There are two kinds of surveying: plane and ____________. __________surveying is the measurement of the earth's surface as though it were a plane (or ______) surface without ________________. For larger areas, however, a geodetic survey, which takes into account the __________of the earth must be made.
The different kinds of measurements in a survey include distances, ____________ (heights of features within the area), boundaries (both man-made and __________), and other physical characteristics of the site. Some of these measurements will be in a horizontal ________; that is, measuring to the force of gravity. Others will be in a vertical __________, in line with the direction of ___________. In plane surveying the principal measuring device for _________is the steel tape. The men who hold the steel tape during a survey are still called ______________ They generally level the tape by means of _________________, which are lead ____________ attached to a line that give the direction of gravity.

Lesson 21

Photogrammetry

Photogrammetry may be defined as the science, art and technology of obtaining reliable information from photographs. It encompasses two major areas of specialisation: metrical and interpretative. The first area is of principal interest to surveyors, since it is applied to determine distances, elevations, areas, volumes and cross-section and to compile topographic maps from measurements made on photographs. Aerial photographs (exposed from aircraft) are normally used, although for certain work, terrestrial photos (taken from earth-based cameras) are employed.

Interpretative photogrammetry involves recognising objects from their photographic images and judging their significance. Critical factors considered in identifying objects are the shapes, sizes, patterns, shadows, tones and textures of their images, This area of photogrammetry was traditionally called photographic interpretation because initially it relied on aerial photos. More recently, other sensing and imaging devices such as multispectral scanners, thermal scanners, radiometers and side-looking airborne radar have been developed which aid in interpretation. These instruments sense energy in wavelengths beyond those which the human eye can see or ordinary photographic film can record. They are often carried in aircraft as remote as satellites; hence, a new term, remote sensing, is now generally applied to the interpretative area of photogrammetry.

Photogrammetry dates back to 1839, and the first attempt to use photogrammetry in preparing a topographic map occurred a year later. Photogrammetry is now the chief method of topographic mapping. Cameras, films, plotting instruments and techniques have been continually improved so that photogrammetrically prepared maps today meet very-high accurate standards. Other advantages of this method of mapping are: speed of coverage of an area, relatively low cost, ease of obtaining topographic details, especially in inaccessible areas and reduced likelihood of omitting data due to the tremendous amount of detail shown in photographs.

Photogrammetry presently has many applications in surveying and engineering. It is used, for example, in land surveying to compute co-ordinates of section corners, boundary corners, or points of evidence that help locate these corners. Large-scale maps are made by photogrammetric procedures for many uses, one being subdivision design. Photogrammetry is used to map shorelines in hydrographic surveying, to determine precise ground co-ordinates of points in control surveying, and to develop maps and cross-sections for route and engineering surveys. Photogrammetry is playing an important role in developing the necessary data for modern Land Information Systems.

Photogrammetry is also being successfully applied in many nonengineering fields - for example, geology, archaeology, forestry, agriculture, conservation, planning, military intelligence, traffic management and accident investigation. It is beyond the scope of this lesson to describe all the varied applications of photogrammetry. Use of the science has increased dramatically in recent years and its future growth for solving measurement and mapping problems is assured.

Aerial cameras

Aerial mapping cameras are perhaps the most important photogrammetric instruments, since they expose the photographs on which the science depends. The must be capable of exposing a large number of photographs in rapid succession while moving in an aircraft at high speed, so a short cycling time, fast lens, efficient shutter and large-capacity magazine are required. Single-lens frame cameras are the type most often used in metric photogrammetry. These cameras expose the entire frame or format simultaneously through a lens held at a fixed distance from the focal plane.

The principal components of a single-lens frame camera are the lens (most important part), shutter to control the interval of time that light passes through the lens, diaphragm to regulate the size of lens opening, filter to reduce the effect of haze and distribute light uniformly over the format, camera cone to support the lens-shutter-diaphragm assembly with respect to the focal plane and prevent stray light from striking the film, focal plane, surface on which the film lies when exposed, fiducial marks, four or eight in number to define the photographic principal point, camera body to house the drive mechanism that cocks and trips the shutter, flattens the film and advances it between exposures, and magazine, which holds the supply of exposed and unexposed film. Images of fiducial marks are printed on the photographs. Aerial mapping cameras are laboratory calibrated to get precise values for the focal length and lens distortions. Flatness of the focal plane, relative position of the principal point with respect of the fiducial marks, and fiducial mark locations are also specified. These calibration data are necessary for precise photogrammetric calculations.

Aerial photographs exposed with single-lens frame cameras are classified as vertical (taken with the camera axis aimed vertically downward, or as nearly vertical as possible) and oblique (made with the camera axis intentionally inclined at an angle between the horizontal and vertical). Oblique photographs are further classified as high if the horizon shown on the picture, and low if it does not. Vertical photographs are the principal mode of obtaining imagery for photogrammetric work. Obliquies are seldom used for mapping or metrical applications, but are advantageous in interpretative work and for reconnaissance.

A truly vertical photograph results if the axis of the camera is exactly vertical when exposure is made. Despite all precautions, small tilts, generally less than 1° and rarely greater than 3°, are invariably present, and the resulting photographs are called near-vertical or tilted photographs. Photogrammetric principles and practices have been developed to handle tilted photos; accuracy is not sacrificed in compiling maps for them.

Although vertical photographs look like maps to laypersons, they are not true orthographic projections of the earth's surface. Rather they are perspective views, and the principles of perspective geometry must be applied to prepare maps from them.

Vertical photographs for topographic mapping are taken in strips which normally run lengthwise over the area to be covered. The strips or flight lines generally have a sidelap (overlap of adjacent flight lines) of about 30%. Endlap (overlap of adjacent photographs in the same flight line) is usually about 60 ± 5% (Fig. 2). If endlap is greater than 50%, all ground points will appear in at least two photographs and some show in three. Images common to three photographs permit aerotriangulation, to extend or densify control through a strip of photographs using only minimal existing control.

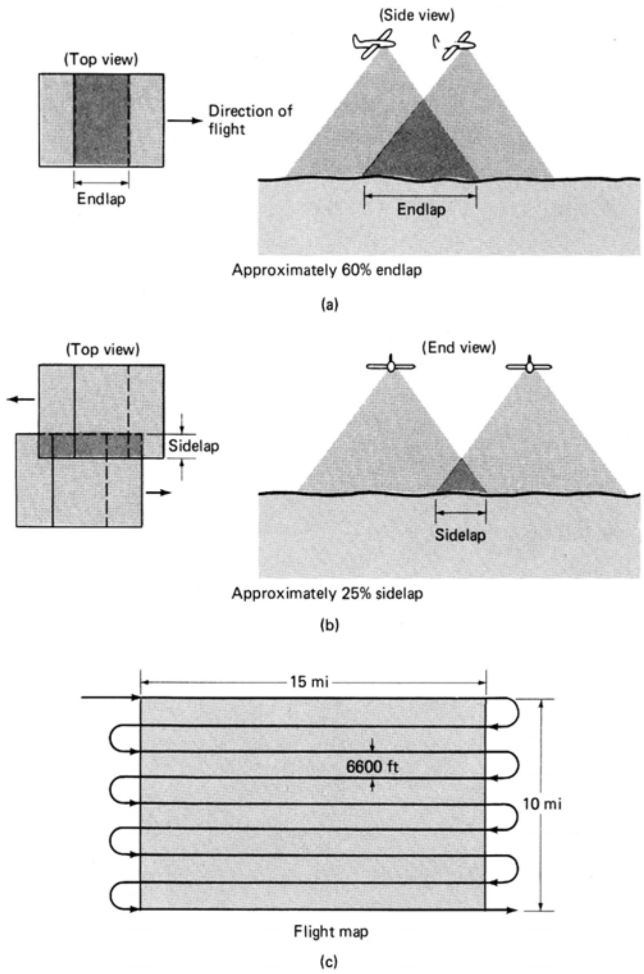

Fig. 16 Endlap, sidelap, and flight map

Remote sensing

In general, remote sensing can be defined as any methodology employed to study the characteristics of objects using data collected from a remote observation point. More specifically, and in context of surveying and photogrammetry, it is the extraction of information about the earth and our environment from imagery obtained by various sensors carried in aircraft and satellites. Satellite imagery is unique because it affords a practical means of monitoring our entire planet on a regular basis.

Remote sensing imaging systems operate much the same as the human eye, but they can sense or "see" over a much broader range than humans. Cameras that expose various types of film are among the best types of remote sensing imaging systems. Nonphotographic systems such as multispectral scanners (MSS), radiometers, side-looking airborne radar, and passive microwave are also commonly employed.

The sun and other sources emit a wide range of electromagnetic energy called the electromagnetic spectrum. X-rays, visible light rays, and radio waves are some familiar examples of energy variations within the electromagnetic spectrum. Energy is classified according to its wavelength. Within the wavelength of visible light, the human eye is able to distinguish different colours. The primary colours - blue, green and red - consist of wavelengths in the ranges of 0.4 to 0.5, 0.5 to 0.6 and 0.6 to 0.7

micrometers respectively. All other hues are combinations of the primary colours. To the human eye, an object appears a certain colour, because it reflects energy of wavelengths producing that colour.

Just as the retina of the human eye can detect variations in wavelengths, photographic films or emulsions can also be made with wavelengths sensitivity variations. Normal colours emulsions are sensitive to blue, green and red energy. Others respond to energy in the near-infrared range. These are called infrared emulsions. They make it possible to photograph energy that is invisible to the human eye. Infrared film is now widely used for a variety of applications such as detections of crop stress, and identification and mapping of tree species.

Remote sensing technology has been applied to locate forest fires, detect diseased crops and tress, study wildlife, monitor floods and flood damage, analyse population growth and distribution, determine locations and extents of oil spills, monitor water quality and detect the presence of pollutants and accomplish numerous other tasks over large areas for the benefit of humankind.

In the future, surveyors will be called on to map land-use activities and extract a variety of other positional types of information from satellite images. This kind of data is needed to develop modern Land Information Systems. Remote sensing will play a significant future role in providing data to assess the impacts of human activities on our air, water and land resources. It can provide information to assist in making sound decisions and formulating politics related to resource management and development, and land-use activities.

EXERCISES AND DRILL

I Points for discussion.

1. Discuss the advantages of preparing maps photogrammetrically.
2. List the principal components of a single-lens frame aerial camera.
3. To what wavelengths of electromagnetic energy is the human eye sensitive?
4. What wavelength produce the colours blue, green and red?
5. Discuss the uses and advantages of satellite imagery.
6. List the nonphotographic imaging systems commonly used in remote sensing.

II Write an abstract for the text "Photogrammetry".

Scheme of an abstract

Procedural approach:

Key words: photogrammetry, application of photogrammetry, instruments, remote sensing

Set up relations between the concepts: guidelines (*defintion and classification of photogrammetry; ald and new mthods and devices; applications pf photogrammetry today; principal equipment; aerial photography; remote sensing – principals and applicatio).*

Suggestions for the introductory sentence: The article summarizes…
The author describes…
The article deals with …
Photogrammetry is …

Lesson 22

Satellite and Inertial Surveying

In recent years two new and unique approaches to surveying have emerged - Satellite Surveying System and Inertial Systems. Both have resulted from research and development conducted by military.

Satellite Surveying Systems grew out of the space program and more specifically from Navy activities related to navigation. The first non-military use of satellites for surveying purposes occurred in the seventies. Since their inception, satellite surveying systems have been increasingly employed in almost all areas of surveying. They are capable of producing results of extremely high accuracy and thus one of their most useful application to date has been in augmenting and strengthening Geodetic Control networks.

Inertial Surveying Systems (ISSs), also sometimes called Inertial Positioning System (IPs), were originally developed as guidance systems for aircraft and missiles. Since 1975, when the first commercial ISS unit became available for non-military use, these systems have been employed in a variety of different types of surveys. Although the first cost of Inertial Surveying Systems is relatively high, point locations can be established rapidly using them. Consequently, they are comparatively economical, especially on large projects.

Both of these new surveying systems can be operated day or night, rain or shine, and neither requires cleared lines of sight between stations. This represents a revolutionary departure from conventional surveying procedures which rely on measured angles and distances for determining point positions.

The first generation of Satellite Surveying Systems operated on the Doppler principle and utilised the Navy's so called TRANSIT navigation satellites. In this system, receivers located at ground stations measure changes in frequencies of radio signals transmitted from satellites. The TRANSIT satellites are in polar orbits around the earth at altitude of about 1075 km.

The development of new navigation and positioning system lead to the launching of the first NAVSTAR (Navigation Satellite Timing And Ranging) satellite. This ushered in the second generation of satellite technology for surveying purposes, which has become known as the Global Positioning System of GPS. The program is still in the development stage but has already gained widespread acceptance.

The operating principle of satellite Doppler system is illustrated in the simplified diagram of Fig. 17. A precise controlled radio frequency is continuously transmitted from the satellite as it passes in orbit above an observing station. When a transmitter approaches a receiver, the received signal has a frequency higher than that transmitted, but it is decreasing. Then as satellite moves away from the station, the frequency decreases below the transmitted level. The phenomenon illustrated in Fig. 18 can be appreciated by anyone who has listened to the change in pitch of a train whistle as it approaches and then moves past. The magnitude of frequency change (Doppler shift), which is a function of the range (distance of the satellite), is measured by receiver. With transmitting frequency, satellite orbit, and precise timing of observations known, the position of a receiving station is computed from the measured Doppler shifts.

As just noted, knowledge of the satellite’s orbit is an essential ingredient for computing positions of Doppler receiving stations. This orbital information can be obtained from either the so-called broadcast ephemeris, or a precise ephemeris.

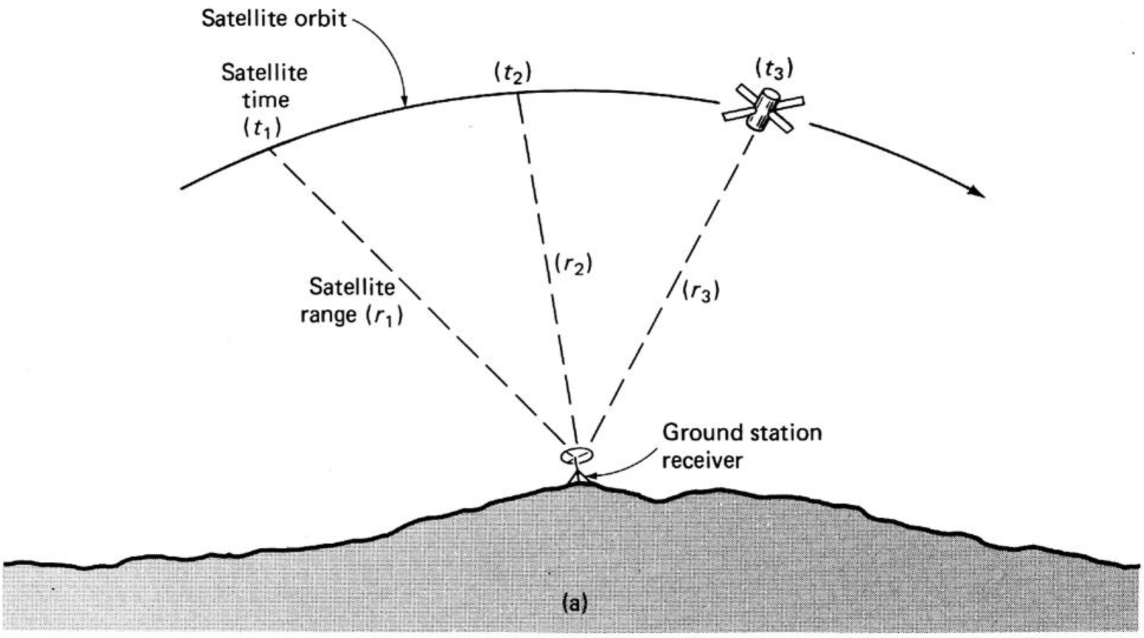

Fig. 17 Satellite and Doppler receiver geometry

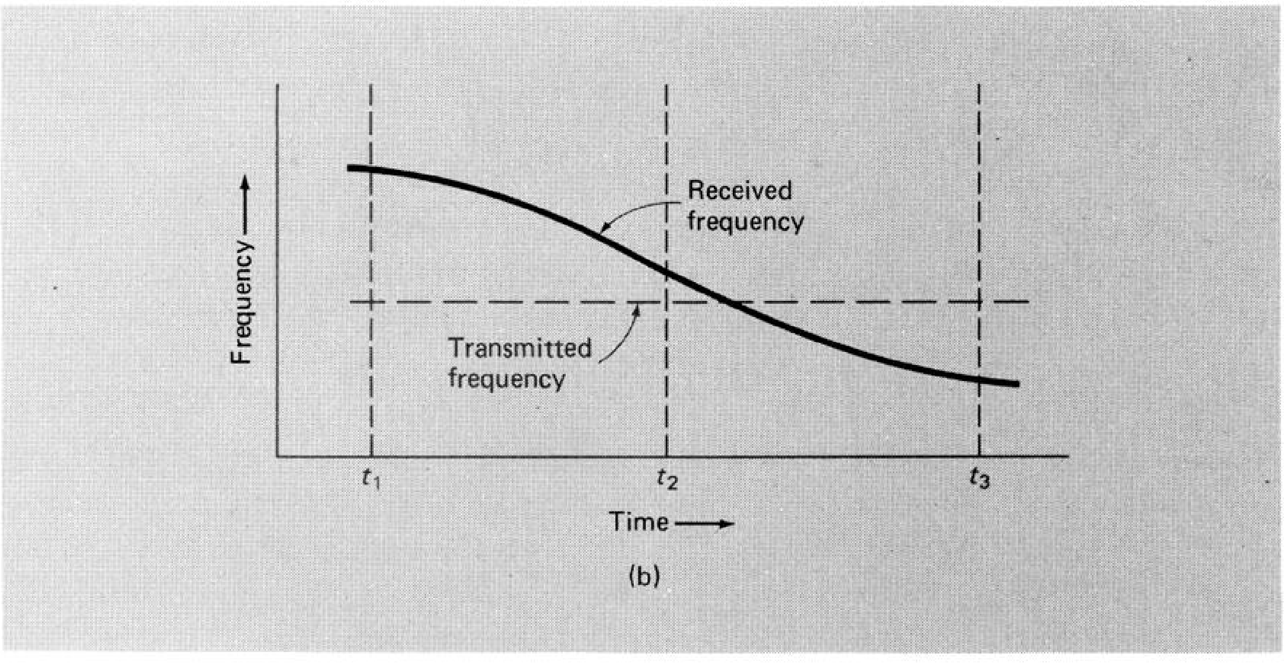

Fig.18 Frequency change (Doppler shift) measured by receiver

The operating principle of Inertial Surveying Systems consists fundamentally in making measurements of accelerations over time. This is done while the instrument is carried from point to point in a land vehicle or helicopter. The acceleration and time measurements are taken independently in three mutually orthogonal planes which are oriented 1) north-south, 2) east-west and 3) in the direction of gravity (up-down). From acceleration and time data, components of the instrument's movement (distances and directions) in each of the three reference directions can be computed, and relative positions of points determined. The major components of an Inertial Surveying System are accelerometers, gyroscopes and a computer.

EXERCISES AND DRILL

I Points for discussion.

1. What is the greatest advantage of satellite surveying system and Inertial Systems in surveying?
2. Describe in short the Doppler principle.
3. Explain the following abbreviations: ISS, IPS, TRANSIT, NAVSTAR, GPS

II Technique of making definitions

In defining a notion which is expressed by a term two stages must be taken into consideration:

Stage 1: Classification of that notion into the broader class to which it belongs.

Stage 2: Specification of that notion, i.e. to give additional specifications which will define it in such a way that a single possible meaining is obtained differing entirely from any other.

Classification	Specification
Satellite is any body	that revolves about another body.
Geodesy is the science	that deals with measurement and mapping of the earth's surface

Make definitions of your own for the words below usign the above given instructions.
Inerial surveying; ephemeris; gravity; receiver; geodetic control network.

III Look at the following definitions of geodesy and say which one is the most appropriate and why.

a. Geodesy is the science concerned with determining the size and shape of the Earth.
b. This is the science that locates positions on the Earth and determines the Earth's gravity field.
c. It is the discipline in which the curvature of the Earth must be taken into account when determining the directions and distances.

Lesson 23

Global Positioning System

The Global Positioning System, like the Doppler program, is based on observations of signals transmitted from satellites. These signals are picked up at ground stations by receivers. The elapsed times for signals to travel from transmitter to receiver are measured, enabling receiver positions to be computed.

GPS satellites are in near-circular orbits at altitudes of about 20,000 kilometres above the earth. The orbits are inclined at an angle of 55° to the equatorial plane and spaced 60° apart. Each satellite travels around the earth twice every sidereal day and it is visible to an observer for approximately 10 hours a day. The geometry and dynamics of the satellite constellation ensure that at any location on earth, at any given time, from four to six satellites are visible.

The current GPS system is based on accurate ephemeris data on the real-time location of each satellite and on a very precisely kept time. It uses the satellite signals, accurate time, and sophisticated algorithms to generate distances in order to triangulate positions anywhere on earth.

The objectives of GPS are twofold - navigation and precise positioning. Of the two, precise positioning is of greater concern to surveyors. GSP procedures for determining precise point positions consist fundamentally in measuring distances from points of unknown location to satellites whose positions are known at the instant of measuring the distances. Conceptually, this is identical to performing conventional resection using distances measured by taping or EDMI from a station of unknown position to three or more control stations. The basic difference is that in GPS the control stations are satellites. The distances are then determined in somewhat different manner.

The method of measuring distance in GPS can be explained in a rudimentary manner with reference to the diagram of Figure 19. Assume that the satellite and a receiver located on the ground station both simultaneously generate an identical series of codes. In the figure, these transmitted codes are illustrated schematically by the sawtooth waves of varying lengths. It will take the satellite's signal some time to travel to the ground receiver, where it is picked up and compared to the signal generated there. The ground receiver is able to make a precise determination of the elapsed time since it generated the same portion of code that it just received from the satellite. Based on the elapsed signal travel time and velocity of propagation of electromagnetic energy through the atmosphere (approximately 186,000 mi/sec), the distance to the satellite can be computed. This general distance-measuring procedure in GPS terminology is called ranging.

For precise distance determination, the procedure just described depends on exact synchronisation of clocks within the satellite and receiver so transmission of the codes is truly simultaneous. This exact clock synchronisation cannot be accomplished. Hence, there is a so-called clock bias or time difference between the two clocks. Therefore, measured elapsed times are somewhat inaccurate which cause distance determinations also to be in error.

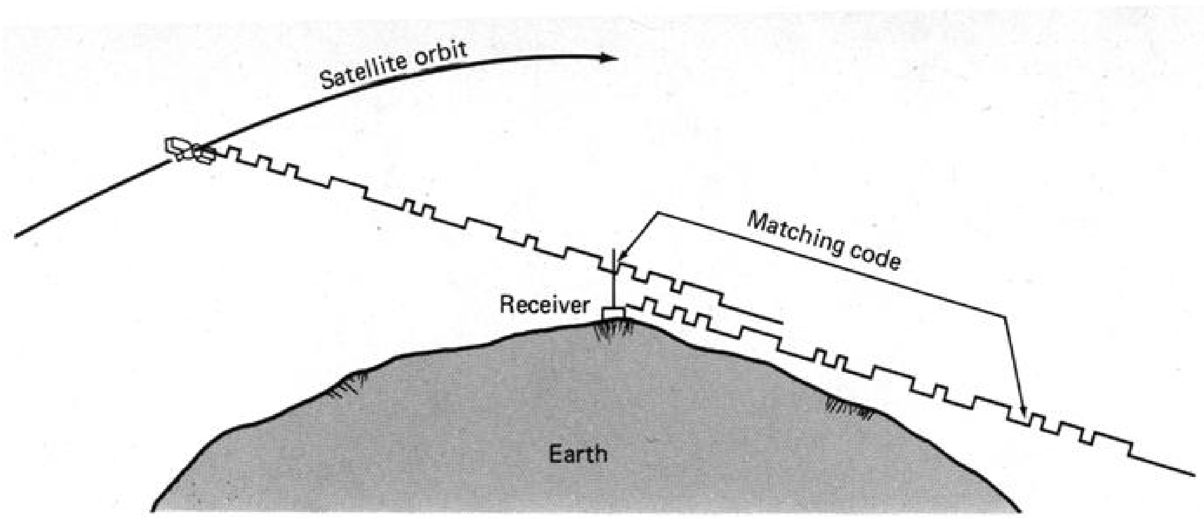

Fig. 19 Code matching concept for measuring distances from GPS receivers to satellites

From the orbital or ephemeris information simultaneously being transmitted by the satellite, its position at the instant the matching portion of signal was transmitted can be determined. If ranges are measured from a ground station to three or more satellites, the position of the ground station can be found. The procedure is similar in concept to the Doppler "point-positioning" technique.

The future of GPS in the practice of surveying seems assured. The systems have already demonstrated reliability and a capability to yield extremely high accuracy. Although the most common application of GPS to date has been for control work, the systems have been used in virtually every type of survey. GPS has been especially useful in solving some heretofore rather difficult problems such as determining positions for hydrographic sounding, locating dredging rigs, and fixing positions of offshore oil wells. New applications are being tested on regular basis, and research and development to improve the system continues. It is expected that in the near future highly accurate real-time positioning will be possible which would make GPS applicable for construction stakeout and many other uses.

With their many advantages such as speed, accuracy, lack of intervisibility requirements between the stations, operational capability day or night and in any weather, in the future, except for surveys of very small scale, GPS could well make conventional surveying by theodolite and tape obsolete.

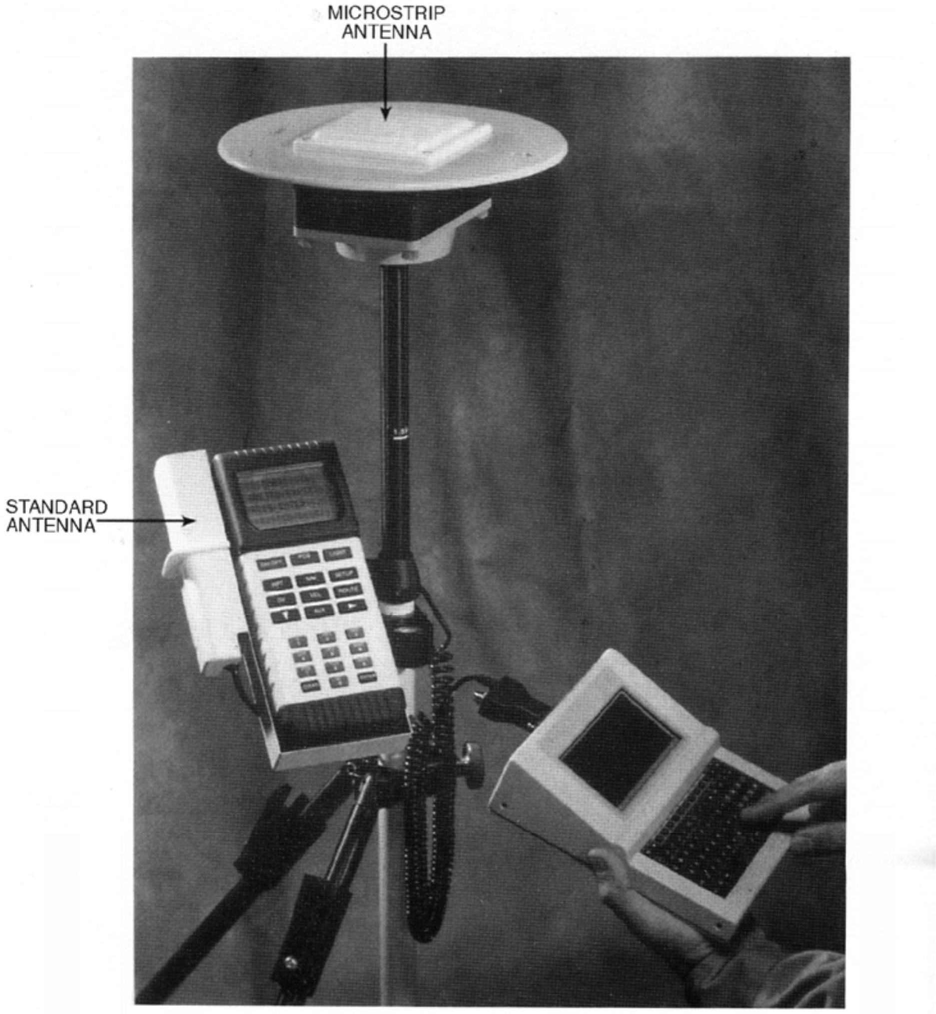

Fig. 20 Magellan 5-channel GPS NavPro 5000 GPS receiver shown with multipath resistant microstrip antenna and data collector

EXERCISES AND DRILL

I Points for discussion.

1. Describe the basic principle of GPS measurements.
Give a few applications of GPS measurements other than for surveying purposes.

II BASIC AND EXPANDED INFORMATION
Syntax in the function of the volume of information in a text.

BASIC INFORMATION: The Global Positioning System is based on the observation of signals.
EXPANDED INFORMATION
a) by adding in the position: The GPS system is based on the observation of signals transmitted from

satellites.

b) interpolating: The GPS measurement which is based on the observation of signals is used for navigation and precise positioning.

c) by contracting in the past position: The GPS system based on the observation of signals is used for navigation and precise positioning.

by contracting in the front position: The GPS system based on the observation of transmitted signals from satellites is used for navigation and precise positioning.

Expand the following information using the above given instructions.

1. The position of a satellite is determined from ephemeris information.
2. Satellites were first used by military and only later they have attracted a wide variety of proposed civil users.

TECHNICAL TERMINOLOGY

ENGLISH-CROATIAN

accidental error	slučajna pogreška
accuracy	točnost
accurate, adj.	točno
acre	jutro, ral
acreage	površina u akrima
adjustment	izjednačenje
aerial camera	zračna kamera
aerial photogrammetry	aerofotogrametrija
aerial photography	zračna fotografija
aeronautical chart	zrakoplovna navigacijska karta
alidade	alhidada
alignment	trasa, iskolčen pravac
altitude	nadmorska visina
area	površina, područje
arithmetic mean	aritmetička sredina
astrolabe	astrolab, instrument koji služi za određivanje astronomskih točaka
astronomic meridian	astronomski meridijan
axis	os
azimuth	azimut
barometric levelling	barometarski nivelman
base for calibration	kontrolna baza, kalibracijska baza (osnovica)
base line	geodetska osnovica
base map	osnovna karta
bench mark	reper
blunder	gruba pogreška
bound	granica
boundary	granica, međa
building site	gradilište
bull's eye bubble	dozna libela, kružna libela
cadastre	katastar
CADD (Computer Aided Drafting and Design)	Računalno oblikovanje i izradba nacrta
calibrate, v.	kalibrirati
Cartesian co-ordinates	pravokutne koordinate
centesimal division	centezimalna podjela
centre up	centrirati
chain	mjerni lanac
chaining pin	klin brojač
chainman	mjerač (figurant)
chart	navigacijska karta
circular level	kružna libela, dozna libela
circumference	opseg
city lot	gradska parcela
code	kod
compensator	kompenzator
compilation	kompilacija, sastavljanje
computer aided drafting	računalna izradba nacrta
condition equation method	metoda uvjetne jednadžbe
construction	izgradnja, građevina
contour	izohipsa
control network	mreža stalnih točaka

control point	stalna, kontrolna točka
control survey	kontrolna izmjera
conversion of co-ordinates	preračunavanje koordinata
cross hairs	nitni križ
cross section	poprečni presjek
curvature	zakrivljenost
cycling time	cikličko vrijeme
data collector	sakupljač podataka
deflection angle	kut nagiba
demarcation	omeđivanje
diaphragm	pločica nitnog križa
digital map	digitalna karta
diopter	diopter, gledača
direction	pravac
discrepancy	odstupanje
distance	udaljenost
distance measurement	mjerenje udaljenosti
distortion	deformacija
dumpy level	nivelir sa spojenim dalekozorom
earth's crust	zemljina kora
earth-based camera	kamera postavljena na tlu
eclipse	pomrčina
Electronic Distance Meter (EDM)	elektronički daljinomjer
elevation	visina
endlap	uzdužni preklop
ephemeris	efemeride, katalog zvijezda
error	pogreška
eyepiece	okular
fiducial mark	rubna markica
field book	zapisnik
field surveying	topometrija (niža geodezija)
field work	rad na terenu
figure of the earth	oblik Zemlje
fine movement screw	vijak za fini pomak
flight line	linija leta
flight map	susjedni red
focal plane	žarišna ravnina
footscrew	podnožni vijak
geodetic control network	geodetska mreža
geodetic latitude	geodetska širina
geodetic longitude	geodetska dužina
geodetic surveying	državna izmjera
geoid	geoid
glass circle	stakleni krug
global coverage	sveopća pokrivenost
global geodesy	viša geodezija
Global Positioning System (GPS)	Sustav za određivanje položaja na Zemlji
grad (USA), grade (UK)	grad
graduated circle	krug s podjelom
gravity field	polje ubrzanja sile teže
grid	pravokutna koordinatna mreža
grid bearing	smjerni kut
ground survey	terestrička izmjera
gyroscope	giroskop
hachured map	karta sa šrafama
hand level	ručna libela
high-order survey	izmjera visoke točnosti
hub	kolčić
hydrographic survey	hidrografska izmjera

inertial surveying system	inercijalni mjerni sustav
inking	crtanje tušem
interior angle	unutrašnji kut
interpolate, v.	interpolirati
interpretative photogrammetry	interpretativna fotogrametrija
invar tape	invarska vrpca
Lambert conformal conic projection	Lambertova konformna konusna projekcija
land consolidation	komasacija
Land Information System	Zemljišni informacijski sustav
land registrar	zemljišno-knjižni voditelj
land registry	zemljišno-knjižni ured, katastar
land survey	izmjera
land title	pravo vlasništva nad zemljištem
large scale	krupno mjerilo
lath	kolčić
layout	iskolčavanje
layout (v.)	iskolčiti
least squares method	metoda najmanjih kvadrata
lettering	opis karte
level	nivelir, libela, razina, visina
level rod	nivelmanska letva
level up, v.	horizontirati
level vial	cijev libele, libela
level, v.	nivelirati
levelling	niveliranje
levelling head	nivelir
levelling rod	nivelmanska letva
licensed surveyor	ovlašteni mjeritelj
line of collimation	os kolimacije
line of sight	vizurna linija
lot number	broj parcele
magnetic bearing	azimut magnetskog meridijana, deklinacioni kut
magnitude	veličina
map projection	kartografska projekcija
mapping	kartiranje
mean earth ellipsoid	srednji zemljin elipsoid
mean sea level	srednja razina mora
medium scale	srednje mjerilo
meridian convergence	konvergencija meridijana
metes and bounds	granice
method of lateral obliques	približno ortogonalno snimanje
metrical photogrammetry	metrička fotogrametrija
micrometer vernier	nonijus, mikrometarski
mine survey	rudarska mjerenja
minor control survey	poligonometrija
misclosure error	pogreška zatvaranja
mistake	zabuna
monument, geodetic	geodetski biljeg, međni kamen
multiple lens camera	višestruka kamera
near-vertical photograph (tilted photograph)	nagnuta fotografija
neat drafting	precizno crtanje
oblique Mercator projection	Mercatorova kosa projekcija
oblique photograph	kosa fotografija
observation	opažanje
observation equation method	metoda jednadžbe opažanja pogreške
observer	opažač
optical plummet	optički visak
orbit	putanja
orthogonal plane	ortigonalna ravnina

orthographic projection	ortografska projekcija
overlay drafting	dopunski prozirni crtež
parallax	paralaksa
parallel plate	paralelna ploča
parallel-plate micrometer	mikrometar s planparalelnom pločom
parcel	parcela
peg	kolčić
permanent monument	stalni biljeg
perpendicular	okomit
photogrammetry	fotogrametrija
plane co-ordinates	ravne koordinate (koordinate u ravnini)
plane grid	horizontalna mreža
plane rectangular co-ordianate	horizontalna pravokutna koordinata
plane surveying	praktična geodezija
plane table	geodetski (mjernički) stol
plate level tube	cijevna libela
plot	parcela
plotter	crtač
plumb bob	visak
plumb line	vertikala, okomica
precise levelling	precizni nivelman
precision	preciznost
prime meridian	početni meridijan
property boundary	vlasnička međa
property corner (USA)	međni kamen
property description (USA), descriptive schedule (UK)	opis gradnje
random error	slučajna pogreška
range pole (USA)	daljinomjerna letva
ranging	iskolčenje (trasiranje)
ranging rod	daljinomjerna letva
real estate	nekretnina
receiver	prijemnik
reconnaissance	rekognosciranje
rectangular co-ordinate	pravokutna koordinata
rectangular grid	pravokutna mreža
redundant measurement	prekobrojno mjerenje
reference meridian	referentni meridijan
reference surface	referentna površina, nulta nivo ploha
remote sensing	daljinsko istraživanje
remote sensor	daljinski senzor
residual	ostatak
residual error	preostala pogreška, odstupanje
retracement survey	obnovljena izmjera
retrieve, v.	učitati
rod	letva
rope stretcher	potezač užeta
satellite image	satelitska snimka
scale	mjerilo
scribing	graviranje sloja
selenodesy	selenodezija
set out, v.	iskolčiti
set up (an instrument), v.	postaviti instrument
sexagesimal division	seksagezimalna podjela
sextant	sekstant
sidelap	poprečni preklop
sidereal day	zvjezdani dan
sight, v.	vizirati
sighting	viziranje
sine curve	sinusoida

single-lens camera	jednostruka kamera
site map	plan građevinskog zemljišta
slope	nagib
small scale	sitno mjerilo
sphere	kugla
spheroid	sferoid
spirit level	libela
split bubble	cijevna libela
spot height	visinska točka
stadia line	daljinomjerna nit
stadium, stadia	stadij, stara jedinica mjere za udaljenost
staff	letva
stake	kolčić
stake out (v.)	iskolčiti
steel tape	čelična vrpca
step counter	brojač koraka
stereographic projection	stereografska projekcija
store, v.	pohraniti
straightedge	ravnalo
strip	red zračnih snimaka
subdivision survey	parcelacija
survey	geodetska izmjera
surveyor	mjeritelj
surveyor's arrow	klin brojač
symbol	grafički element, kartografski znak
systematic error	sistematska pogreška
tacheometry	tahiometrija
tangent screw	vijak za fini pomak
tape	mjerna vrpca
taping	mjerenje vrpcom
target	cilj, meta
taping pin	klin brojač
telescope	dalekozor
tellurometre	telurometar
terrestrial photo	terestrička fotografija
theodolite	teodolit
thermal source	toplinski izvor
tide gauge	mareograf
tilting axis	horizontalna os
tilting level	nivelir s elevacijskim vijkom
tilting screw	elevacijski, nagibni vijak
tilt-sensing mechanism	mehanizam koji bilježi nagib
tinting	nijansiranje
title deed	isprava o pravu vlasništva
topographic feature	topografski oblik
tracing	precrtavanje
transit	tranzit, teodolit
transmitter	prijenosnik
transverse Mercator projection	Gauss-Krügerova projekcija
travelling microscope	pomični mikroskop
traverse	poligonski vlak
traversing	poligoniranje
triangulation	triangulacija
tripod	tronožac
true meridian	pravi meridijan (zemljopisni)
true value	prava vrijednost
tube bubble	cijevna libela
unknown, n.	nepoznanica
vernier	nonijus

vernier theodolite	teoedolit s nonijusom
vertical control	visinska kontrolna izmjera
vertical hill shading	fotiranje uz okomito osvjetljenje
vertical photograph	vertikalna zračna fotografija

CROATIAN-ENGLISH

aerofotogrametrija	aerial photogrammetry
alhidada	alidade
aritmetička sredina	arithmetic mean
astrolabe	astrolab, instrument za određivanje astronomskih točaka
astronomski meridijan	astronomic meridian
azimut magnetskog meridijana, deklinacioni kut	magnetic bearing
azimut	azimuth
barometarski nivelman	barometric levelling
broj parcele	lot number
brojač koraka	step counter
centezimalna podjela	centesimal division
centrirati	centre up
cijev libele, libela	level vial
cijevna libela	plate level tube, tube bubble
cikličko vrijeme	cycling time
cilj, meta	target
crtač	plotter
crtanje tušem	inking
čelična vrpca	steel tape
dalekozor	telescope
daljinomjerna letva	range pole (USA), ranging rod
daljinomjerna nit	stadia line
daljinski senzor	remote sensor
daljinsko istraživanje	remote sensing
deformacija	distortion
digitalna karta	digital map
diopter, gledača	diopter
dopunski prozirni crtež	overlay drafting
dozna libela, kružna libela	bull's eye bubble
državna izmjera	geodetic surveying
efemeride, katalog zvijezda	ephemeris
elektronički daljinomjer	Electronic Distance Meter (EDM)
elevacijski, nagibni vijak	tilting screw
fotiranje uz okomito osvjetljenje	vertical hill shading
fotogrametrija	photogrammetry
Gauss-Krügerova projekcija	transverse Mercator projection
geodetska dužina	geodetic longitude
geodetska izmjera	survey
geodetska mreža	geodetic control network
geodetska osnovica	base line
geodetska širina	geodetic latitude
geodetski (mjernički) stol	plane table
geodetski biljeg, međni kamen	monument, geodetic
geoid	geoid
giroskop	gyroscope
grad	grad (USA), grade (UK)
gradilište	building site
gradska parcela	city lot
grafički element, kartografski znak	symbol
granica	bound, boundary
granice	metes and bounds
graviranje sloja	scribing
gruba pogreška	blunder
hidrografska izmjera	hydrographic survey
horizontalna mreža	plane grid
horizontalna os	tilting axis
horizontalna pravokutna koordinata	plane rectangular co-ordianate
horizontirati	level up

inercijalni mjerni sustav	inertial surveying system
interpolirati	interpolate
interpretativna fotogrametrija	interpretative photogrammetry
invarska vrpca	invar tape
iskolčenje	layout, ranging
iskolčiti	layout, set out, stake out
isprava o pravu vlasništva	title deed
izgradnja, građevina	construction
izjednačenje	adjustment
izmjera visoke točnosti	high-order survey
izmjera	land survey
izohipsa	contour
jednostruka kamera	single-lens camera
jutro, ral	acre
kalibrirati	calibrate
kamera postavljena na tlu	earth-based camera
karta sa šrafama	hachured map
kartiranje	mapping
kartografska projekcija	map projection
katastar	cadastre
klin brojač	chaining pin, taping pin
kod	code
kolčić	hub, lath, peg, stake
komasacija	land consolidation
kompenzator	compensator
kompilacija, sastavljanje	compilation
kontrolna baza, kalibracijska baza (osnovica)	base for calibration
kontrolna izmjera	control survey
konvergencija meridijana	meridian convergence
kosa fotografija	oblique photograph
krug s podjelom	graduated circle
krupno mjerilo	large scale
kružna libela, dozna libela	circular level
kugla	sphere
kut nagiba	deflection angle
Lambertova konformna konusna projekcija	Lambert conformal conic projection
letva	rod, staff
libela	spirit level
linija leta	flight line
mareograf	tide gauge
međni kamen	property corner (USA)
mehanizam koji bilježi nagib	tilt-sensing mechanism
Mercatorova kosa projekcija	oblique Mercator projection
metoda jednadžbe opažanja pogreške	observation equation method
metoda najmanjih kvadrata	least squares method
metoda uvjetne jednadžbe	condition equation method
metrička fotogrametrija	metrical photogrammetry
mikrometar s planparalelnom pločom	parallel-plate micrometer
mjerač (figurant)	chainman
mjerenje udaljenosti	distance measurement
mjerenje vrpcom	taping
mjerilo	scale
mjeritelj	surveyor
mjerna vrpca	tape
mjerni lanac	chain
mreža stalnih točaka	control network
nadmorska visina	altitude
nagib	slope
nagnuta fotografija	near-vertical photograph (tilted photograph)

navigacijska karta	chart
nekretnina	real estate
nepoznanica	unknown
nijansiranje	tinting
nitni križ	cross hairs
nivelir s elevacijskim vijkom	tilting level
nivelir sa spojenim dalekozorom	dumpy level
nivelir	levelling head
nivelir, libela, razina, visina	level
niveliranje	levelling
nivelirati	level
nivelmanska letva	level rod
nivelmanska letva	levelling rod
nonijus	vernier
nonijus, mikrometarski	micrometer vernier
oblik Zemlje	figure of the earth
obnovljena izmjera	retracement survey
odstupanje	discrepancy
okomit	perpendicular
okular	eyepiece
omeđivanje	demarcation
opažač	observer
opažanje	observation
opis gradnje	property description (USA), descriptive schedule (UK)
opis karte	lettering
opseg	circumference
optički visak	optical plummet
ortigonalna ravnina	orthogonal plan
ortografska projekcija	orthographic projection
os kolimacije	line of collimation
os	axis
osnovna karta	base map
ostatak	residual
ovlašteni mjeritelj	licensed surveyor
paralaksa	parallax
paralelna ploča	parallel plate
parcela	parcel, plot
parcelacija	subdivision survey
plan građevinskog zemljišta	site map
pločica nitnog križa	diaphragm
početni meridijan	prime meridian
podnožni vijak	footscrew
pogreška zatvaranja	misclosure error
pogreška	error
pohraniti	store
poligoniranje	traversing
poligonometrija	minor control survey
poligonski vlak	traverse
polje ubrzanja sile teže	gravity field
pomični mikroskop	travelling microscope
pomrčina	eclipse
poprečni preklop	sidelap
poprečni presjek	cross section
postaviti instrument	set up
potezač užeta	rope stretcher
površina u akrima	acreage
površina, područje	area
praktična geodezija	plane surveying
prava vrijednost	true value

pravac	direction
pravi meridijan (zemljopisni)	true meridian
pravo vlasništva nad zemljištem	land title
pravokutna koordinata	rectangular co-ordinate
pravokutna koordinatna mreža	grid
pravokutna mreža	rectangular grid
pravokutne koordinate	Cartesian co-ordinates
precizni nivelman	precise levelling
precizno crtanje	neat drafting
preciznost	precision
precrtavanje	tracing
prekobrojno mjerenje	redundant measurement
preostala pogreška, odstupanje	residual error
preračunavanje koordinata	conversion of co-ordinate
približno ortogonalno snimanje	method of lateral obliques
prijemnik	receiver
prijenosnik	transmitter
putanja	orbit
računalna izradba nacrta	computer aided drafting
Računalno oblikovanje i izradba nacrta	CADD (Computer Aided Drafting and Design)
rad na terenu	field work
ravnalo	straightedge
ravne koordinate (koordinate u ravnini)	plane co-ordinates
red zračnih snimaka	strip
referentna površina nulta nivo ploha	reference surface
referentni meridijan	reference meridian
rekognosciranje	reconnaissance
reper	bench mark
rubna markica	fiducial mark
ručna libela	hand level
rudarska mjerenja	mine survey
sakupljač podataka	data collector
satelitska snimka	satellite image
seksagezimalna podjela	sexagesimal division
sekstant	sextant
selenodezija	selenodesy
sferoid	spheroid
sinusoida	sine curve
sistematska pogreška	systematic error
sitno mjerilo	small scale
slučajna pogreška	accidental error
slučajna pogreška	random error
smjerni kut	grid bearing
srednja razina mora	mean sea level
srednje mjerilo	medium scale
srednji zemljin elipsoid	mean earth ellipsoid
stadij, stara jedinica mjere za udaljenost	stadium, stadia
stakleni krug	glass circle
stalna, kontrolna točka	control point
stalni biljeg	permanent monument
stereografska projekcija	stereographic projection
susjedni red	flight map
Sustav za određivanje položaja na Zemlji	Global Positioning System (GPS)
sveopća pokrivenost	global coverage
tahiometrija	tacheometry
telurometar	tellurometre
teodolit	theodolite
teoedolit s nonijusom	vernier theodolite
terestrička izmjera	ground survey

terestrička fotografija	terrestrial photo
točno	accurate
točnost	accuracy
toplinski izvor	thermal source
topografski oblik	topographic feature
topometrija (niža geodezija)	field surveying
tranzit, teodolit	transit
trasa, iskolčen pravac	alignment
trasiranje	laying out, setting out
triangulacija	triangulation
tronožac	tripod
učitati	retrieve
udaljenost	distance
unutrašnji kut	interior angle
uzdužni preklop	endlap
veličina	magnitude
vertikala, okomica	plumb line
vertikalna zračna fotografija	vertical photograph
vijak za fini pomak	fine movement screw, tangent screw
visak	plumb bob
visina	elevation
visinska kontrolna izmjera	vertical control
visinska točka	spot height
viša geodezija	global geodesy
višestruka kamera	multiple lens camera
viziranje	sighting
vizirati	sight
vizurna linija	line of sight
vlasnička međa	property boundary
zabuna	mistake
zakrivljenost	curvature
zapisnik	field book
zemljina kora	earth's crust
Zemljišni informacijski sustav	Land Information System
zemljišno-knjižni ured, katastar	land registry
zemljišno-knjižni voditelj	land registrar
zračna fotografija	aerial photography
zračna kamera	aerial camera
zrakoplovna navigacijska karta	aeronautical chart
zrčana fotografija	aerial photograph
zvjezdani dan	sidereal day
žarišna ravnina	focal plane

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