THE DIFFERENT DIMENSIONS OF WHERE

A workbook on survey tools

2

Anupama Pai

FERAL

Foundation for Ecological Research, Advocacy and Learning

सत्यमेव जयते

Catalysed and supported by
Rashtriya Vigyan Evan Prodyoggiki Sanchar Parishad (NCSTC),
Department of Science and Technology, New Delhi.

Publisher:
Foundation for Ecological Research,
Advocacy and Learning
P.O.Box 28
Pondicherry - 605 001, India
E-mail: feralin@feralindia.org
Web: http://www.feralindia.org

Design : Gopinath S., http://www.photoessays.net

Printed at:
All India Press
Kennedy Nagar
Pondicherry 605 001

Acknowledgment

I would like to thank Dr. Neil Pelky, Srinivas V. and R. S. Bhalla for comments and inputs into preparing the manual, help with graphics and information.

Table of Contents

Chapter 1 :	Where ?	5
	A little bit of history	6
	Astrolabe	6
	Cross-staff	8
	The sextant	8
	The compass	9
Chapter 2 :	The compass	11
	Latitude and longitude	12
	The modern compass	12
	Starting to use the compass	13
	Mapping your school campus	14
	Drawing your map from your data	17
	Finishing your map	17
Chapter 3 :	The Sight Level, adding elevation information	20
	Understanding the readings	26
	Starting the survey	32
Chapter 4 :	Linking Maps to GIS	35
	Global Positioning System	37
	Activity Section	39
	Activity 1	39
	Activity 2	40
	Activity 3	41
	Activity 4	42
	Activity 5	43
	Fact File 1	46
	Fact File 2	47
	Fact File 3	48
	Fact File 4	49
	Fact File 5	50
	Solutions	51

How To Use This Manual

This manual has been written in the style of a workbook. Users will find that the concepts are first introduced and are then followed by some questions, exercises or activities. You are encouraged to do these in the space provided in the workbook. Solutions, if any, are given at the end of the book. Read, experiment and have fun!

Chapter 1:

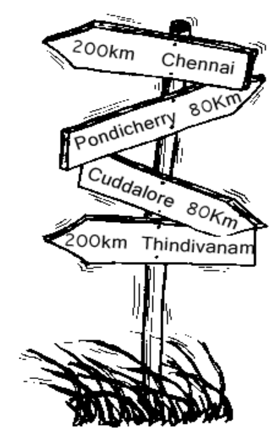
Where ?

Where ? A simple word. We use it daily and the answers we get are many. But the common points in all the answers are two things -

direction : left or right, north or south,
distance : how far - few houses away, streets away, near a landmark, meters, km, etc.

In this workbook we go through the steps of how to read a map and the different ways in which we have found our way around the world. Starting with the stars in ancient times and the use of different instruments through the ages, we look at the common instruments of today. We will also do a set of simple exercises to understand the use of standard equipment used in surveys. Using the information collected we then go through the steps of making maps of our local area.

This manual is for you to learn about simple instruments and use them to understand the basic concepts. So do try out the exercises and activities outlined along the way.



A LITTLE BIT OF HISTORY

Maps have been created in different ways over the centuries. But, the purpose of a map has always remained the same - to show locations, relation of these to other locations and details of a specific area as accurately as possible. This is also the basic information required to go from one place to another. The way a map is drawn has changed from simple sketches to elaborate artistic drawings to more specific representations of the details required. The accuracy or how "correct" the picture is with reference to the real world has advanced along with the development of mathematics and survey tools. Yet, the basic principles of map drawing have not changed.

Before the invention of survey instruments, travellers used the sun, moon and stars to help find their way and developed their maps based on these observations. Their location in the sky and the way they move across it was observed carefully. The time the traveller took to move from one location to another was also carefully noted with the help of hour glasses. The height and position of the same stars were noted at these different times and this was used to calculate location. Celestial bodies - such as the stars - are so far from the earth that they appear to be located on the inside surface of an imaginary hollow sphere. This sphere - which has an infinite radius - is called the celestial sphere. Its center coincides with the center of the earth. This fact was used in making the calculations.

Some of the initial instruments used were the astrolabe, sextant and cross staff. The compass which was also used was improved upon constantly and became widely used given its simplicity.

THE ASTROLABE

An astrolabe is a two-dimensional model of the celestial sphere. The name has its origins from the Greek words *astron* and *lambanien* meaning "the one who catches the heavenly bodies". It was at the time the most used, multi-purpose astronomical instrument. Its many uses included locating and predicting the positions of the Sun, Moon, planets and stars, determining local time given local longitude and vice-versa, surveying and triangulation. Astrologers of the Islamic world and European nations used astrolabes to construct horoscopes.

Historically, astrolabes were elaborately inscribed brass discs. No one knows for certain who invented the astrolabe, but it was the chief

Astrolabe

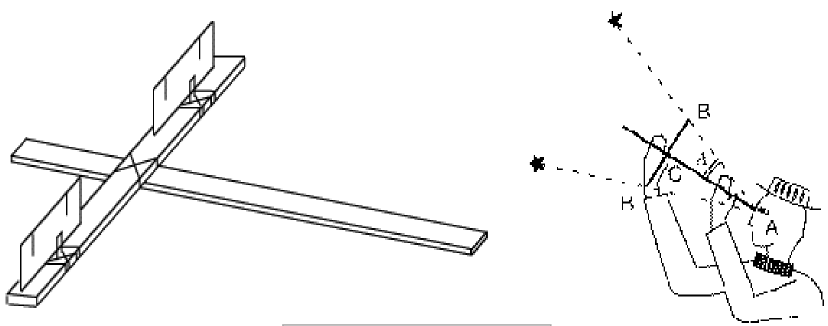
navigational instrument until the invention of the sextant in the 18th century. Some credit the invention to Hipparchus (2nd century BC). The first person credited for building the astrolabe in the Islamic world is reportedly Fazari, a Persian. They were improved and more features were added to them until the Middle Ages, by which time they had become very complex instruments. Geoffrey Chaucer from England wrote one of the best descriptions of the astrolabe and its use in 1392.

The most important part of the traditional astrolabe was a circular metal plate, about 6 inches in diameter, which could be suspended by a ring so as to hang perfectly vertical. On one side of the disk (the "back") were engraved several circles divided by different kinds of gradations, such as 360 degrees, 365 1/4 parts for the days, 12 for the months, etc. The engravings could be used for trigonometric calculations. The other side of the plate (the "front") was also engraved with an outer circle of 24 divisions for the hours. Another circle was divided as a calendar using the zodiacal constellations. The tropics and equator were engraved in the central part, the celestial pole being at the center of the disk.

Another disk could be fixed on the front side of the astrolabe so that it could rotate. Many openings were cut into that disk in order to let the astronomer see through to the body of the astrolabe. These cuts were made in order to form a map of the sky: a broad annulus corresponding to the zodiac (divided by the constellations) and several "tongues" or "flames" pointing to important stars. Thin engraved disks or paper could also be put between the sky disk and the astrolabe body. By adjusting the "sky" disk, it was possible to determine the visible part of the sky, the altitude of celestial bodies, etc. A ruler, called the *alidade*, was fixed on the back of the astrolabe. Suspending the instrument by its ring, one could measure the altitude of a celestial body by pointing at it with the ruler, and reading the measurement off one of the engraved circles.

THE CROSS STAFF

It is said to have been invented by Rabbi Levi ben Gershon (1288-1344), a Jewish scholar who lived in Provence, in southern France. The cross-staff was used for measuring the angle between the directions of two stars. Though older instruments for this purpose existed, they could not be carried around easily. This made the cross-staff very suitable for navigation at sea. It consisted of a long staff with a cross piece which could slide back and forth on it. The cross piece had several slits placed at equal distances. To measure the angle between two stars, an astronomer would place the staff just below one eye and slide the cross-piece up and down. This was done until two equi-distance slits covered each of the stars he was interested in. After this the instrument was lowered and the angle measured. Using simple trigonometry the angle between the two stars was measured. Generally the cross staff was used to find the latitude by measuring the altitude of the pole star above the horizon. Several modifications were made over time, such as more cross pieces and length of staff.

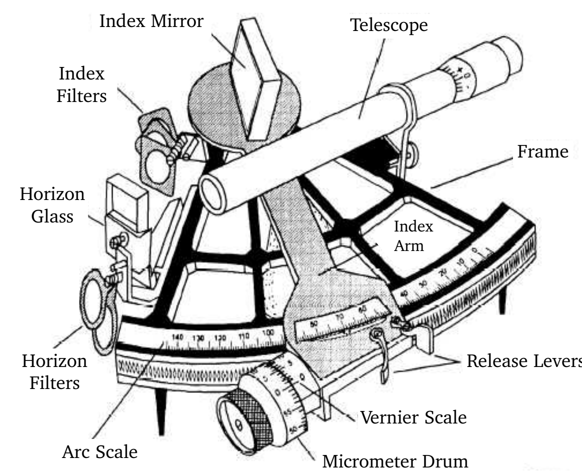


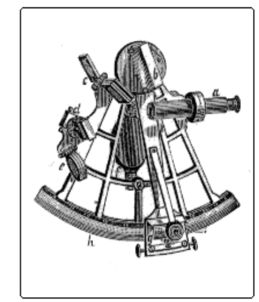
Cross staff

THE SEXTANT

A sextant is a measuring instrument generally used to measure the angle of elevation of a celestial object above the horizon. The scale of a sextant has a length of 1/6 of a full circle or 60°, hence the name - sextant. The angle, and the time when it was measured, were used to calculate a position line on a nautical chart. A common use of the sextant was to sight the sun at noon to find one's latitude. Held horizontally, the sextant could be used to measure the angle between any two objects, such as between two lighthouses, which would also allow for calculation of a line of position on a chart.

It also consisted of a telescope for viewing objects, an index arm, several scales for measurement and an index mirror to reflect objects onto the horizon glass. Half of the horizon glass was silvered to act as a mirror to be able to see the reflection and the other half was clear to look at another object directly. The reflected object was brought in line with the other object by moving the index arm along the arc scale. Thus both objects would be viewed through the horizon glass. The readings on the different scale would then be used to calculate the angle between the two objects.





Sextant

THE COMPASS

A compass is an instrument containing a freely suspended magnetic element which displays the direction of the horizontal component of the Earth's magnetic field at the point of observation. The lodestone is a mineral that contains iron oxide and is therefore magnetic. A piece of this will always arrange itself in a north-south direction. Early records date back to around 200 BC when Chinese fortune tellers used the loadstone to make their predictions. Their use in finding out directions on Earth began with the discovery that the loadstone always oriented itself to the pole star (North star). The first recorded use of the compass for navigation are the seven ocean voyages of Zheng, from China between 1405 and 1433.
Early design of the compass

- A spoon shaped lodestone placed on a square board marked with the four directions and the other reference points such as constellations.
- An iron needle rubbed on lodestone and placed on straw floating in a bowl of water
- Magnetised needles instead of lodestones began to be used around 8th century in China and become common as navigation tools on ships.
- Needles resting on a pivot point similar to modern compasses.
- Over time the way in which the magnetic needle was set up changed giving us our present day compass.

Old Compass

Box Compass

Float Compass

Modern Compass

Chapter 2:

The Compass

In this chapter we will learn to use some basic survey instruments which we will then use to make some maps of our school and local area. But before we start using these instruments, let us refresh our memory on some basics.

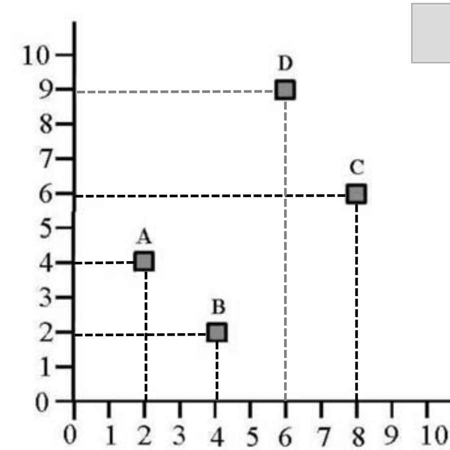
THE CO-ORDINATE SYSTEM

The process of mapping involves the identification of distances and directions to or from different points in a given area. This involves the use of co-ordinates, or a two digit reference system which gives us relative locations of different points. This helps us mark and locate points in an area. For example, how do you find your seat in a theatre - alphabets tell you the row and the number tells you the seat in that row. It can be compared to covering the Earth with a large graph sheet and labelling the locations.

Look at the graph in figure 2.1. The position of the points marked A, B and C are read as 2,4; 4,2 and 8,6 respectively. The first number is the label given to the grid mark on the horizontal line or "x axis" and the second is the label on the vertical line or "y axis".

Q : Can you tell what are the co-ordinates of the point marked D?

Figure 2.1



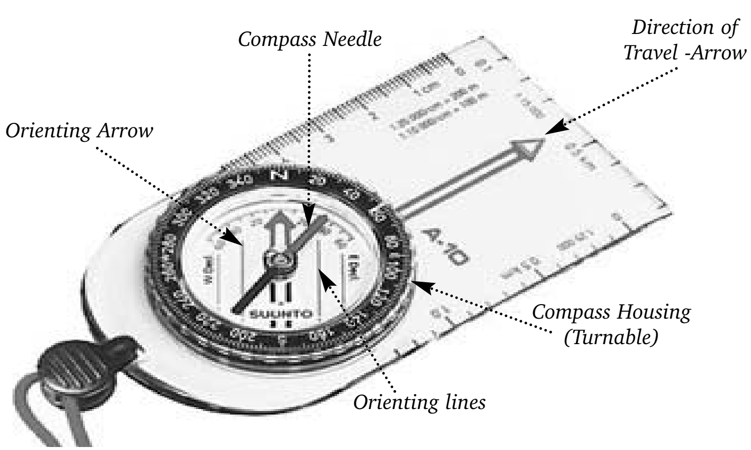
LATITUDE AND LONGITUDE

Latitudes and longitudes are familiar words. Every map has these lines marked on it. These are the graph sheet lines on the Earth's surface. They give us the co-ordinates of places and that is how we are able to find them. This coordinate system uses angular measurements to describe a position on the surface of the earth. The system has been in use, with little change, since the astronomer Ptolemy used them in his first world atlas in A.D. 150.

Latitudes are lines that run around the earth in the horizontal direction and give us the location in the North - South direction. Longitudes are the lines that run from pole to pole and give us the location in the East - West direction.

Q : If you wanted to show latitude and longitude on a graph sheet, which would be on the x axis and which one on the y axis?

THE MODERN COMPASS



The compass that we use commonly today is a very simple and easy to use device. While there are several models, all compasses have the following basic parts.

Compass needle : This is an arrow at the center of the compass, typically in two colours: red and black or red and white. The red point always points to the earth's magnetic North.

Compass housing : This is a movable disc with a scale marked from 0 to 360 degrees on it. The letters N, S, E and W for the four directions North, South, East and West, are also marked.

Direction arrow : This arrow is used to point in the direction that we want to travel.

Orienting lines : These lines are used to find out the direction of travel when a map is used.

STARTING TO USE THE COMPASS

It is very important to learn to hold the compass properly. Only when the compass is flat will the compass needle rotate freely. Place the compass in your hand with the direction arrow pointing away from you. Take care that the palm of your hand is flat and the compass rests on it. Move your hand around to see if the compass needle rotates freely. Now you are ready to set your compass.

Finding North : Look at the compass needle, the red arrow will be pointing North. Now turn the compass housing carefully until the N mark on it is exactly in line with the compass needle. The compass is now set to north and you can start mapping your area of interest.

Needle North Aligned

Take care

Be sure that it is the red part of the arrow which is pointing to the North on the compass housing. Otherwise you will always be going in the direction exactly opposite to that you actually want to go in.

Taking a bearing : This is the reading on the compass housing which is in line with the direction arrow. This tells you in which direction you are facing. For the figure below this can be read as either South - West, or in degrees as 240 degrees.

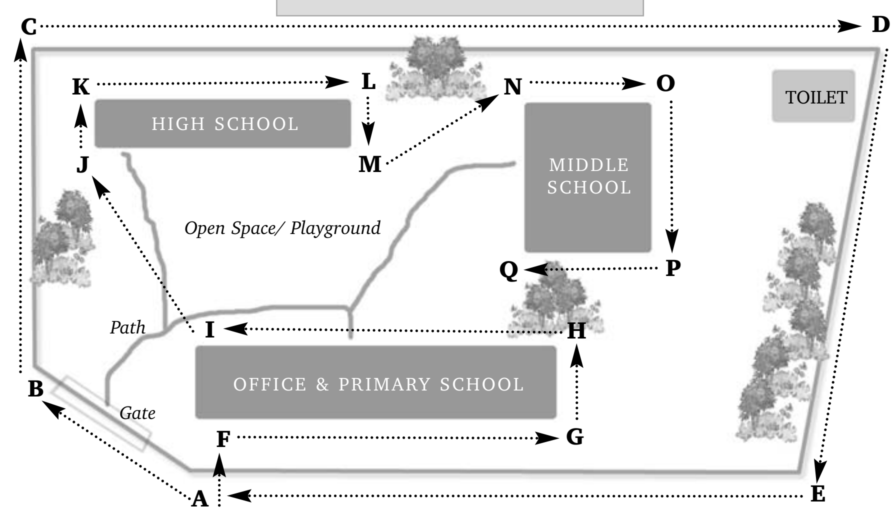
Q : Can you tell the compass readings on the two figures below?

MAPPING YOUR SCHOOL CAMPUS

Now we shall start using the compass on field to make a map of our school. Use the sketch map and table below as a guide. To start the mapping exercise, identify one point which is a permanent feature which can be used as a benchmark. For eg. the entrance gate to the school is a good one. This will be our reference point and will have the co-ordinates 0,0. All our readings will now be taken relative to this location. Now follow the steps given below and using the data sheets that are provided write down your information. Use the column marked description to write down information such as the name of building (eg. office block, canteen, primary school) or any other information that will help you identify the data that you collect.

	A	B	C	D	E
1					
2		**Survey Title**	School campus Survey		**Surveyors**
3		**Date**	5th Nov 05		Murali, Gita, Arun
4					
5	**Sl. No.**	**Location**	**Direction**	**Distance**	**Remarks**
6	1	A – B	305	5	Survey starts at corner of gate wall
7	2	B – C	355	16	
8	3	C – D	90	42	
9	4	D – E	215	30	
10	5	E – A	270	18	
11	6	A – F	30	3	Survey to building starts
12	7	F – G	90	10	
13	8	G – H	360	4	
14	9	H – I	270	10	
15	10	I – J	330	12	Moving to next building
16	11	J – K	360	4	
17	12	K – L	90	7	
18	13	L – M	180	4	
19	14	M – N	45	6	Moving to next building
20	15	N – O	90	8	
21	16	O – P	180	10	
22	17	P – Q	270	8	Survey completed
23					

Sketch Map of School Campus



Tip: *Walk around the area to be surveyed and decide the direction you want to take. Make a sketch of the location so that you can mark out the different points. Mark the serial number of your data sheet on the sketch map to easily identify the route you have taken.*

Survey Title:		Surveyors:		
Date				
Sl No.	Location	Direction	Distance	Remarks
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

1. Set North using the compass needle.
2. Now identify the first point you want to map and find the direction (the angle reading on the compass). Make sure you put a marker at these points.
3. Measure the distance to this point using a meter tape or step counts.
4. Repeat the steps 2 and 3 till you finish the perimeter, that is, until you come back to your starting point.
5. To mark the positions of the buildings within the campus use the points you have marked along the boundary.
6. Take the nearest point to a building, take the direction and distance to a corner.
7. Walk around the building, noting down each corner by taking down the distance and direction. (Your bearings will normally change by 90° since most buildings are rectangular)
8. Repeat steps 6 and 7 to map all the buildings on the campus.

DRAWING THE MAP FROM YOUR DATA

We now have all the information we need to make a map of our school. To draw the map we need

- A large graph sheet
- Protractor or Compass
- Scale
- Pencil

Identify the scale at which you will draw your map on the graph sheet. A simple way to do this is to calculate the distances you have across the school from your sketch map - from left to right and top to bottom. See how large your graph sheet is - how many units does it have across the width and length? Divide the maximum distances by the number of units, and work out the scale you need to use.

Where do you start from?
The bench mark is your starting point. Again look at your sketch map to see where your bench mark is; in one corner, the centre or somewhere in between. Locate it in approximately the same place on your graph sheet. Now start drawing your map using the compass and ruler. Follow the same sequence as on your data sheet. Use the description column to name the points and buildings.
Use different symbols and colours to show different types of objects.

FINISHING YOUR MAP

You should have the following items on your map:

- Title
- Legend
- Scale bar
- Names of main points on the map

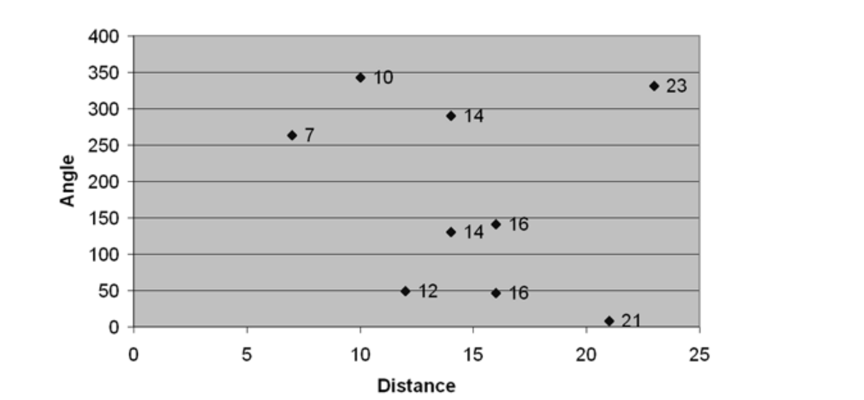
Using a spreadsheet on a computer
You can also draw your compass survey by entering the data on a computer. Look at the figure ## below. Assume your starting point is (0,0). The x and y co-ordinates can be calculated using simple trigonometry.

X co-ordinate = Sin(Angle) * Distance
Y co-ordinate = Cos(Angle) * Distance

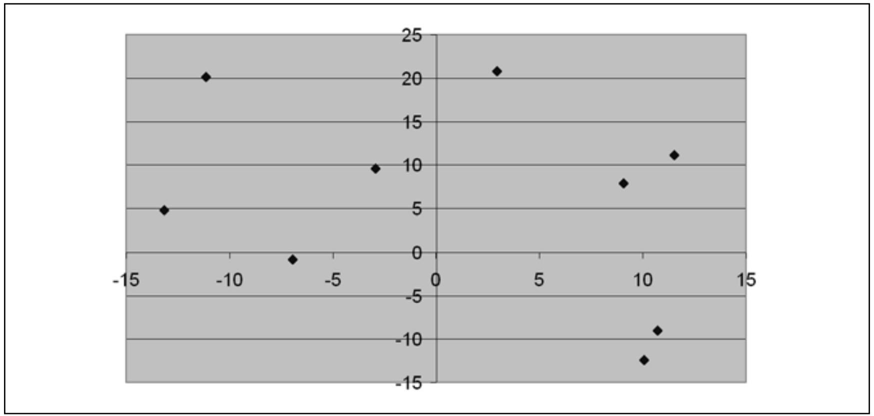
This works fine for the first quadrant (point A) where both the values are positive. However, as we move to the other quadrants the signs start becoming negative (look at Figure ## in Chapter 3 section 5). We solve this problem by changing the angles from degree to the radian form, which the computer can then easily use to calculate the correct x and y co-ordinates. Figure ## shows the results of plots obtained using raw data (degrees) and by converting to radians. Note that the plot with raw data is wrong.
X co-ordinate = Sin(radians(Angle reading)) * Distance
Y co-ordinate = Cos(radians(Angle reading)) * Distance

Now enter and plot your compass survey points and you will have your compass survey as a graph.

Plotting Raw Data Values



Plotting Using Radian Conversion



Distance	Angle in degrees	X co-ord	Y co-ord
14	290	-13.156	4.788282007
14	130	10.7246	-8.99902654
16	46	11.5094	11.11453393
21	8	2.92264	20.79562944
23	331	-11.151	20.11625326
12	49	9.05651	7.872708348
10	343	-2.9237	9.56304756
7	263	-6.9478	-0.8530854
16	141	10.0691	-12.4343354

Step counts: *Walk the distance between two points several times. Make sure you walk normally. Count the number of steps as you walk. Do this five to ten times. Take the average number of steps that you need to walk this distance. Measure it exactly using a meter tape. Now calculate the distance that you cover in each step using the following formula*

Exact distance between two points / average number of steps = distance covered in each step

Remember each person will cover a different distance when she or he walks! What do you think happens to step counts when you walk up or down a steep slope?

The Sight Level : Adding elevation information

The third piece of information on maps is the heights of places or what is called the topography of the area. These are shown as contour lines, or lines which connect places with the same height. Topographical surveys are done to see which way the land slopes and by how much. This is useful for planning roads, putting electric lines, building houses, doing landscaping, etc. How is this information collected? Several instruments are available from simple to very complex. The most commonly used and simplest instrument is the dumpy level or sight level. We will first see how this instrument is used and then re-look at the school campus survey exercise to add in the height information to it.

THE SIGHT LEVEL

1 Parts of a sight level

The various parts of a sight level are shown in figure 3.1. Here is a brief description of each of them.

View finder : This is the bulk of the instrument and consists of an eye piece, a prism, and a lens. This is what you see through. You often need to focus the view finder by using the screw next to the eye piece so that the cross wires are clearly visible.

Focus screw: This is a screw to the right of the view finder which helps you focus the stadia rod. The focus changes as your assistant moves around and you may need to use it fairly often.

Degree scale: This is a circular scale, normally at the base of the view finder. It rotates when twisted. You will need to set this each time the setup moves. It works as the compass on your sight level. However, some sight levels may not have this scale.

Fixing screw: This is a small screw that allows you to fix the view finder so that its circular movements are constrained.

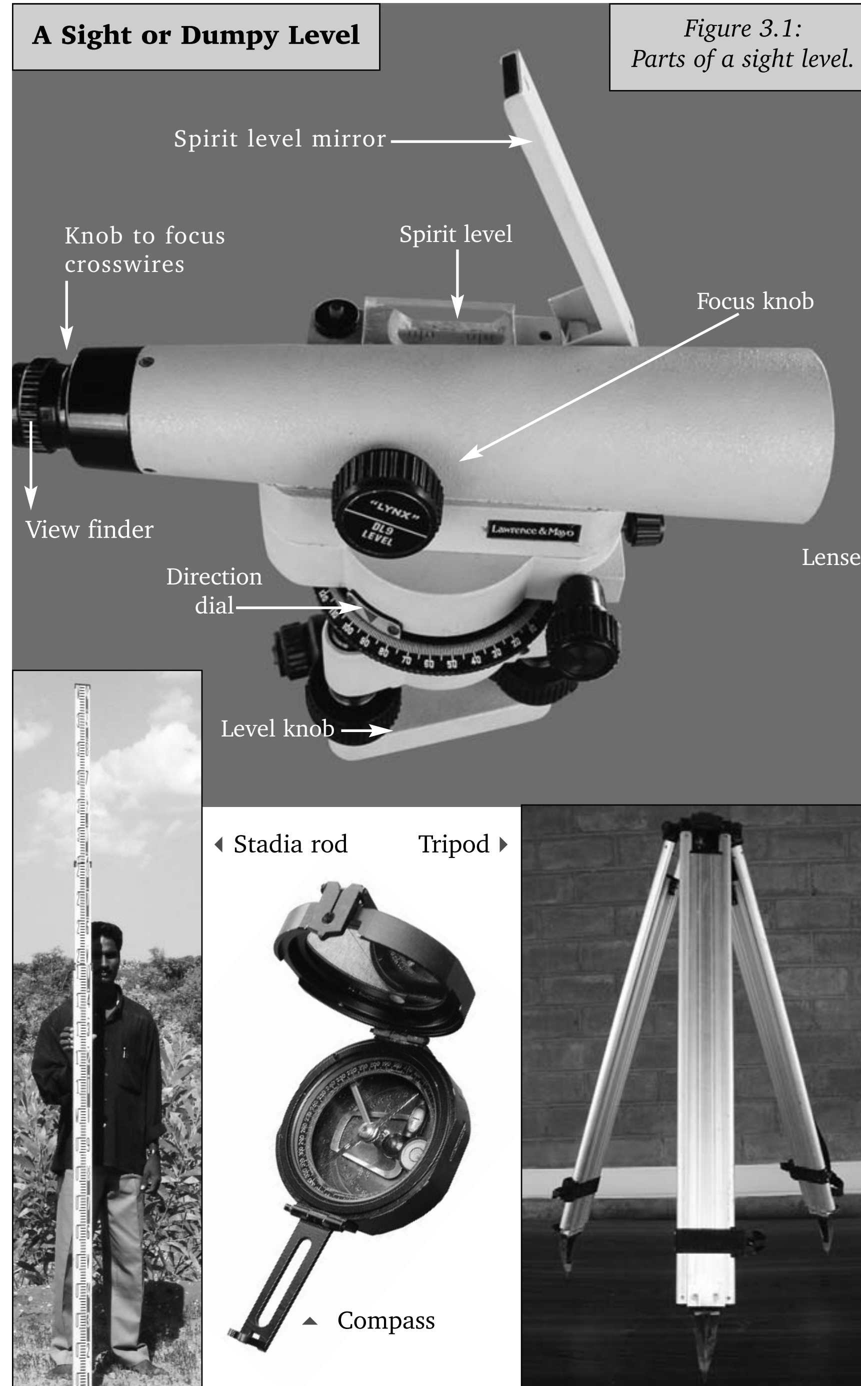


Figure 3.1: Parts of a sight level.

2. Setting up a sight level

Now let us see how one uses it to collect data. The three basic steps you need to know are

1. Setting up the sight level
2. Taking measurements
3. Converting the data into x, y and z co-ordinates

The sight level is actually a combination of four instruments. These are

1. The view finder or sighting instrument.
2. The tripod stand on which it is mounted.
3. The staff gauge or stadia rod, from which the readings are taken.
4. A compass.

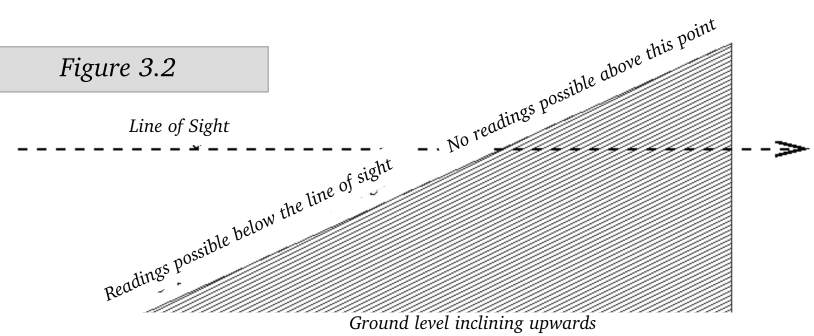
Many sight levels do not come with a built in compass and you need to use a separate compass while surveying.

> *Setting up the sight level is the most crucial part of the survey. Any mistake here will lead to inaccuracies during the survey which could be serious enough to have to redo the entire exercise. To set up a sight level you need to perform the following tasks.*

(a) Placing the instrument

Place the tripod firmly and mount the level so it is more or less horizontal to the ground. Ensure the sighting instrument is at a convenient height, not only for the observer, but from the standpoint of the survey. For example, if you are going to be surveying up hill, the sight level should be high enough for you to take a substantial number of observations. If it is too low, you will only be able to take a few sightings and will have to move the set up repeatedly, making the calculations cumbersome and the results more inaccurate (figure 3.2).

Figure 3.2



(b) Setting the spirit level

Use the spirit level which is built into the sight level to ensure it is exactly horizontal. This is a bit of a skill, but is easily acquired. The fundamental trick is:

- First place the sight so it is parallel to two of the level screws, get the air bubble to the centre of the spirit level.
- Rotate the sight 90 degrees and use the level screw under the eye piece to re-adjust the spirit level.

You may have to repeat this exercise a few times to get the desired result.

> *Test whether the spirit level remains in the centre at all angles by rotating the view finder. If it does not, your settings are not correct. Fix them before continuing.*

(c) Setting the compass

Set the compass calibration on it so that due North shows up as (figure of arrow). To do so you need to follow these steps.

- Place yourself (with a compass) so that the instrument is between you and the stadia rod.
- Direct (by seeing through the compass) the person with the stadia rod to move about 15 to 25 meters away so that she is exactly north of you and the sight level is exactly between you and this person.
- Go to the sight level and rotate it so that it is looking at the stadia rod.
- Go back again and re-check whether the sight level is exactly between you and the assistant. If there is an error, direct her to move accordingly.
- Set the sight level again. Repeat this until you are sure that the stadia rod is exactly north of the sighting instrument.

Once you are satisfied with the position, set the degree scale to zero. Hereafter, each reading you take will be in relation to due North. This is shown in figure 3.3

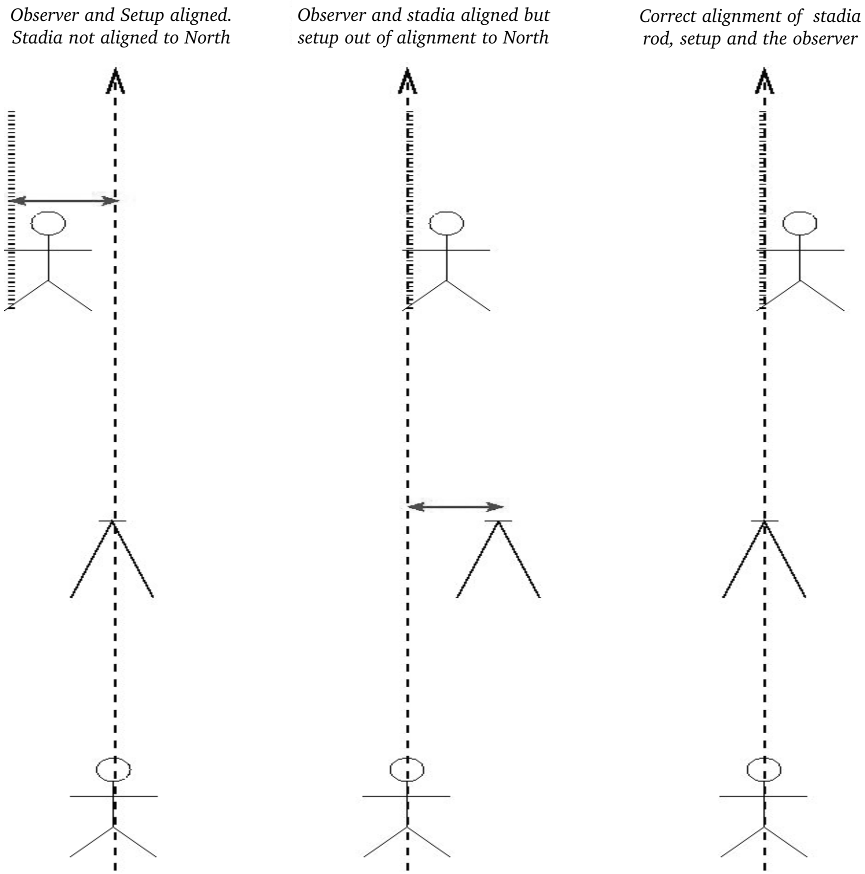


Figure 3.3

3. Starting the survey

In normal circumstances, it takes between 5 to 10 minutes for the set up to be organised. Once this is done you might want to jump into the action. Wait! Remember the rules for field surveys. Do you have the following:

- A format for writing down the data (data sheet).
- A pencil (not a pen) for noting down the observations and an eraser to correct mistakes.
- A camera or diary to note down `additional information about the site.

If your answer is yes let us move on. But a few basics first.

(a) Data sheets

This is a simple sheet with columns to put in the information you collect. It ensures that you do not miss out any details and also helps you record information neatly and clearly. In addition, carry a field diary which you can use to write down observations and also make sketch maps of your survey. Examples of various datasheets are found in the subsequent pages.

(b) Readings

There are four basic readings that you take at each point.
These are

- Compass bearing
- Top reading
- Middle reading
- Bottom reading

The last three are the readings of the stadia rod at the three cross hairs on the view finder (figure 3.4)

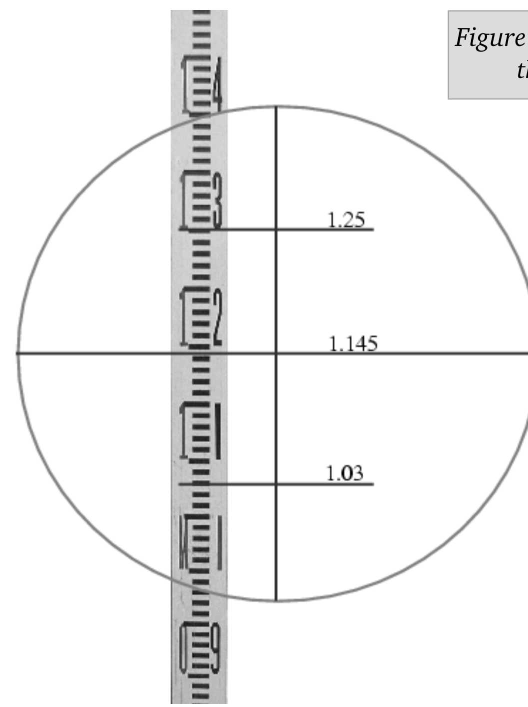


Figure 3.4 Readings from the view finder.

UNDERSTANDING THE READINGS

Calculating height readings with a sight level can be a bit confusing because the reading of the stadia rod is actually is depth and not its height. In other words the height is the negative of the stadia rod reading. Just think about it, the reading you see is from the view finder (which is above ground level) in a straight line to the stadia rod. The actual level you are interested in is the height of the base of the stadia rod. In order to keep things simple, we will take this up at end of our calculations.

There are three different kinds of readings one takes during the field survey.

(i) Benchmarks (BM)
These are permanent or semi-permanent locations which act as the base reference for your survey.

- They provide the ``basic coordinates" off which the rest of your survey is done. This coordinate may be arbitrary and can be given the co-ordinates x = 0, y = 0, z = 0 or you might use a GPS (later perhaps) to get the exact x, y and/or z value.
- They can be used by subsequent survey teams who might want to re-do a survey or position themselves on the map you created.
- They are often highly visible and serve as landmarks.

This the very first measurement you take when you begin a survey. Later, when you analyse the data, you will re-calculate each reading in reference to the benchmark.

(ii) Fore sight (FS)
This is the more common of the measurements made and corresponds to the points at which the stadia rod is kept along your line of survey.

(iii) Backsight (BS)
This is the measurement taken from a new set up point to the previous point. It gives you the relation between the different set up locations.

Other Data Recorded
For each of the points that you survey you need to record the following

- *Distances*

One of the nicest things about sight levels is that they can be used to calculate distances as well as heights. You do not need to do a separate

measure. To calculate the distance all that you need to do is subtract the height of the top reading from the bottom and multiply the result by 100.

(Bottom - Top) x 100 = Distance

- *Compass Bearing*

The compass bearing is simply read off the scale on the view finder. This is why the North setting has to be accurate and you should not move the scale while rotating the instrument.
Let us now look at the datasheet with a set of readings from a survey

Sl.No.	BenchMark			Fore sight			Back Sight			Compass bearing
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	
1 BM	6	4	2							45
2 FS				8	7	6				35
3 FS				3	2	1				56
4 FS				8	6	4				89
5 FS				6	4	2				76
6 FS				9	8	7				99
7 BS							7	6	5	33
8 FS				3	2	1				67
9 FS				9	8	7				36
10 FS				11	9	7				69
11 FS				6	5	4				76

Each reading should be on a separate line to avoid confusion while calculating the real values as shown in the example above (we have kept whole numbers to make things simple).

Now for calculating the heights
The middle reading is all we are interested in while dealing with heights. Remember, what we are calling heights are actually depths or minus height.

Height of the instrument (HI)
The trick for height calculations is to figure out the height of the instrument (that of the view finder when you setup the sight level) or **HI**. The HI of the first setup (where the sight level is first used) is simply the

reading obtained (middle value) when looking at the benchmark. Remember the benchmark is always set at the coordinates x,y,z as 0,0,0 for these calculations. So for reading number 1 the HI = 4.

Actual reading (AR)

If an instrument is placed at a height of 4 and its first fore sight (reading 2) is 7, then clearly the actual reading is 4+7=11or AR = HI+FS. Thus the actual heights for readings 2, 3, 4, 5 and 6 are:

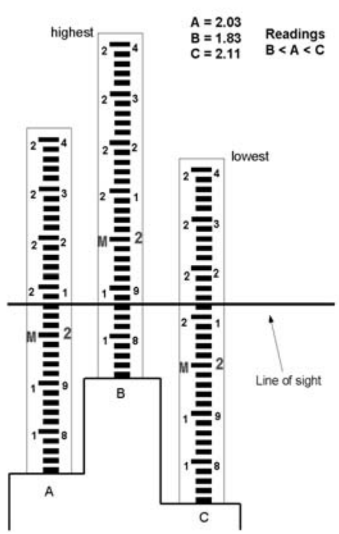
4+7=11 4+2=6 4+6=10 4+4=8 and 4+8=12

Backsight (BS)

Look at serial number 7. It is the reading taken when you move the setup to a new location. This reading (height = 6) corresponds to the same point as measured in serial number 6 whose FS value is 8 and actual height value is 12. In other words the actual value BS serial number 7 should be equal to the actual value of FS number 6. Or BS actual value = 12. Therefore the height of the instrument at the new set up 2 is 12-6=6. The formula is HI=AR-BS.

For the next set of fore sight readings the actual height values are calculated using this new HI value.

Figure 3.5: Stadia heights



Moving higher or lower along a slope? The middle reading tells you that. This is illustrated in the diagram below. So higher the number, lower the elevation.

4. Analysis and plotting

There are three calculations that need to be done while mapping with a sight level

1. Actual Co-ordinates from the raw data (x, y and z)
2. Co-ordinates (x and y) with reference to the benchmark
3. Height (z) with reference to the benchmark

The readings we get from the sight level are the angle and the top, middle, bottom cross-hair readings. Using these four readings we do all the calculations necessary. Look at the graph in Figure 3.6. Let us assume that our set up or instrument (I) is located at the centre of the graph (0,0). The table 01 gives us the actual locations (x,y) of the points A, B,C and D from the BenchMark location 0,0. The table also shows us what happens to the locations of these same points when the instrument is moved to locations I1 and I2.

Figure 3.6: Location of the points and instrument

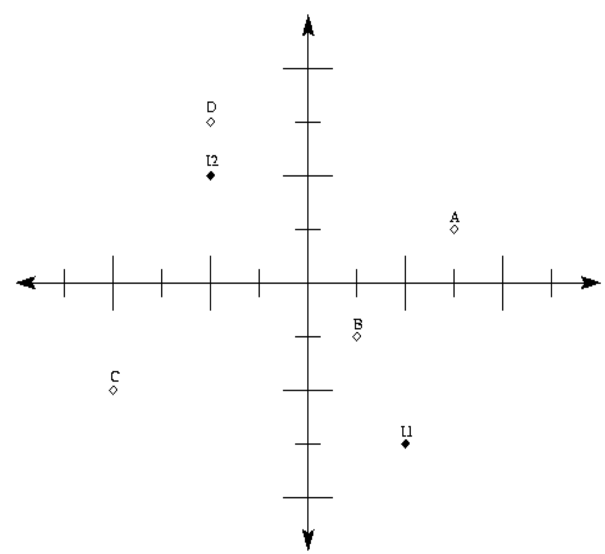


Table 01: Calculating X and Y.

Stn.						
	X	Y	X	Y	X	Y
BM	0	0	-2	3	2	-2
A	3	1	1	3	5	-1
B	1	-1	-1	2	3	-3
C	-4	-2	-6	1	-2	-4
D	-2	3	-4	6	0	1
11	2	-3	0	0	3	-5
12	-2	2	-4	5	0	0

To calculate x and y co-ordinates, we use simple trigonometry - the formula for Sin and Cos. Figure ## shows how.

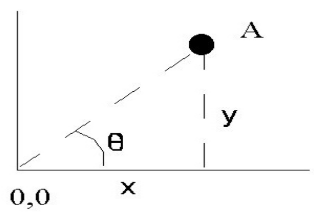


Figure 3.7

The same data sheet used to enter the data is recreated on the computer for calculations. We add columns to calculate the x and y locations. The x and y co-ordinate are also calculated just as the heights were calculated - in relation to the height of the instrument.

We build in the following formula for calculating the x and y co-ordinates of the different points using the compass bearing and distances. The formulae are as below
X instrument = Sin(radians(Angle reading BM) * Distance BM * -1
Y instrument = Sin(radians(Angle reading BM) * Distance BM * -1

For the foresights
X co-ordinate = Sin(radians(Angle reading) * Distance) + Instrument X co-ordinate
Y co-ordinate = Cos(radians(Angle reading) * Distance) + Instrument Y co-ordinate

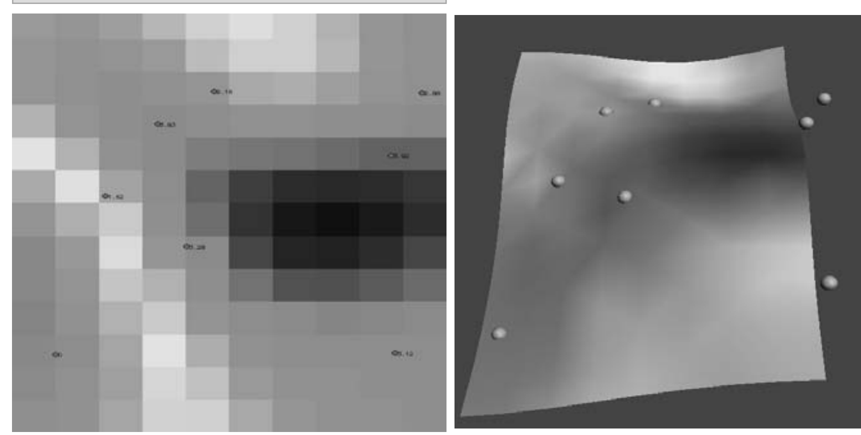
The difference between the calculations for the compass traverse and this is that one has to add the instrument co-ordinate values to each of the readings.

Look at the examples given below and the output one gets.

Table 02: Height Calculations

		Benchmark			Foresight			Foresight					Actual Reading (height)
Sl.No.		Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom	Angle	**HI**	
1	BM	0.66	0.59	0.52							239	0.59	
2	FS				1.08	1.03	0.98				284		1.62
3	FS				1.62	1.57	1.52				332		2.16
4	FS				2.34	2.29	2.24				29		2.88
5	FS				2.77	2.69	2.61				18		3.28
6	BS							1.27	1.24	1.21	264	2.04	
7	FS				1.84	1.79	1.74				313		3.83
8	FS				1.91	1.88	1.85				35		3.92
9	FS				1.12	1.08	1.04				153		3.12
10	FS				0.99	0.92	0.85				168		2.96

Figure 3.9: dumpy 2d and dumpy 3d



Note : One should do a simple cross check with the dumpy raw data to avoid mistakes. The condition tested is
(Top reading - Middle reading) = (Middle reading - Bottom reading)
If the values are equal, your readings are correct. If not then you have made an error. Thus it is good to do a quick mental check each time a reading is taken.

STARTING THE SURVEY

Let us see how the survey of the school campus can now be done along with a dumpy level. This will help us look at the height differences across the campus. You need two people, one to take the readings from the viewfinder and the other to hold the stadia rod at the different points. The first reading that we need to take is that of the benchmark. Then we continue by taking height readings of all the points at which we took the compass and distance readings. Select a place for the instrument set up. Remember try to get the best line of sight and look around so that you can cover the maximum area from a single point. The aim should be to finish the survey with the least number of Turning Points.

Once the instrument is set up, start your survey and move along the points in the same sequence, if possible, as you did for the compass survey. Use the data sheet provided to note down your readings. Remember to have your sketch map as a reference.

After finishing the survey, we need to calculate the relative heights of all the places. This is required as the readings have to include the height of the instrument itself and also the changes in height when we move the set up. Look at the example given in the table below. Now use the formulas and the empty table provided to calculate the heights from your survey.

Now you need to put these heights onto the map prepared with the compass survey. Shade the area from high points (darker) to low points (lighter). Remember the larger the number the lower the elevation at the point.

Figure 3.10: Schematic representation of stadia movement

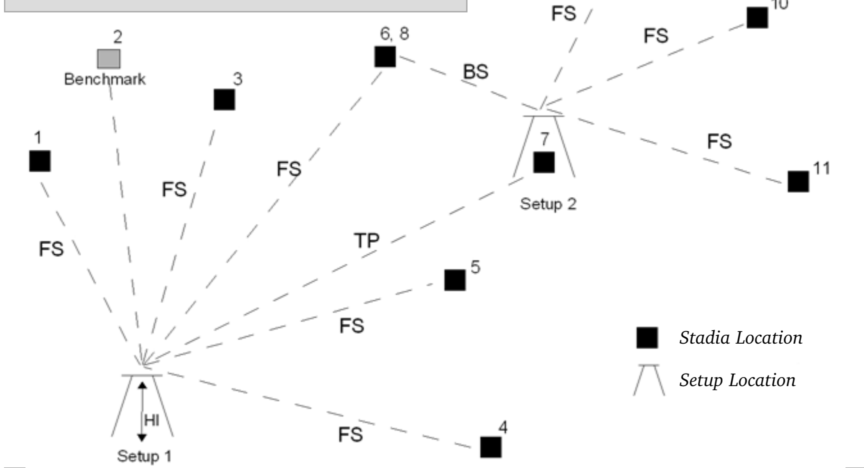


Table 03: Datasheet for survey

Date									
Location									
Surveyor									
	Fore Sight				Back Sight				
Stadia Location	Top	Middle	Bottom	Angle	Top	Middle	Bottom	Angle	Remarks

To what extent did the distances that you got from the compass survey using step counts differ from this one, the dumpy level calculations? Take a meter tape and measure a few distances accurately. What differences do you find? Does it make any difference to the survey or any planning that you may do with this information?

Mathematics and Maps

In the two exercises that you have done and the maps that you have drawn you have used several mathematical concepts. Proportions (or scale) and trigonometry (directions) form a major part of the mapping process. In fact, the development of many mathematical procedures or theorems went hand in with calculating the size of the Earth and trying to depict the round surface on a flat plane.

Chapter 4

Linking Maps to a GIS

In the earlier manual we introduced Geographic Information Systems and saw how it can work. As we saw, it is a system of tools and technologies that are used to show information of different kinds which come from the same area. Let us now look at the map of school that we have made and see what information can be show in it and how this can be done. At this point in time we will only discuss how we organise the information. Once we are familiar with the basics we will move onto using computers and a simple GIS program, MapMaker, in the next module.

What are the different types of information that we can have about our school?

- number of buildings
- location of open ground
- paths
- type of building
  - number of rooms in each building
  - level of classes (primary, middle...) in each building
  - number of students
  - presence of offices, stores, hostel, library, etc.

- information on students
  - number in each class
  - average age

Can you think of any other information that can be collected about the school?

All the information goes into building the database (or the information set) for the school. Different kinds of maps can be prepared using this information. Each set of information is called a theme. A map showing a particular kind of information is known as a thematic map. The example below show the thematic map of number of students in the buildings and the number of class rooms in each building.

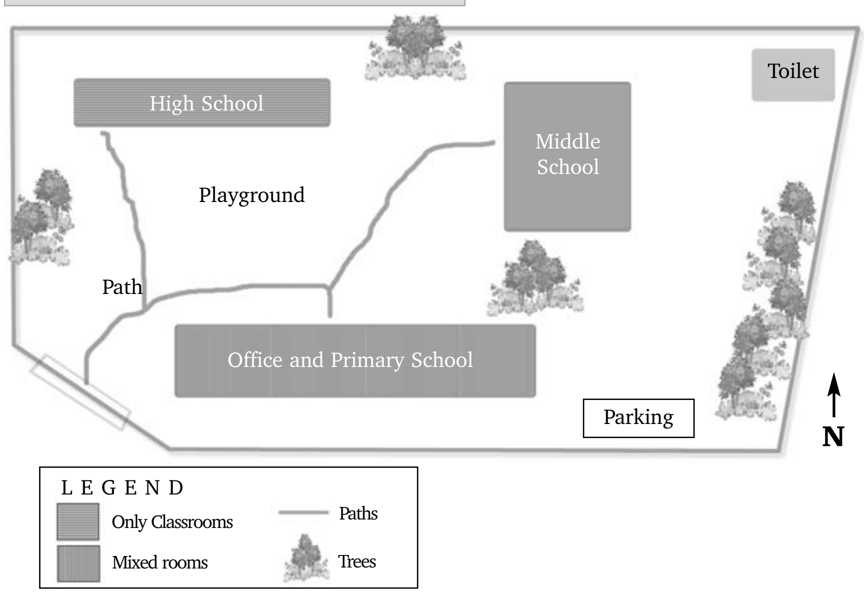
Table 04: Building details

Building Type	No.of Rooms	Classes	No.of Students	Toilet Present	Office Present
Primary and Administration	29	1 to 5	675	Yes	Yes
Middle	18	6 to 7	642	No	No
High	12	8 to 10	660	Yes	No

Table 05: Classroom details

Building Type	Classes	No.of Rooms	Students / Room
Primary	1	5	27
	2	5	29
	3	5	25
	4	5	26
	5	5	28
Middle	6	4	39
	7	6	41
	8	6	40
High	9	6	54
	10	6	56

Figure 4.1: School map with Legend



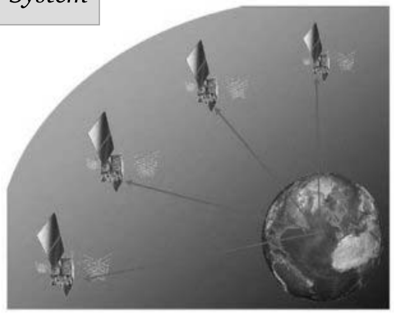
GLOBAL POSITIONING SYSTEM

Once we start using GIS in different application, the use of the Global Positioning System (GPS) becomes common. The GPS is a small powerful receiver which picks up signals from a set of satellites. As its name indicates - it helps give us the position or where we are currently on the globe. Remember, the globe has been covered by an enormous graph sheet. Thus we get the co-ordinates of our location. These co-ordinates are used to analyse satellite imageries, make large scale plans for development (eg, roads, location of minerals).

There are 24 GPS satellites which transmit signals and they circle the globe in three perpendicular orbits . They are positioned in such a manner that from any point on the ground there are at least three satellites visible. These satellites are tracked from ground stations and the position and orbital path of these satellites is stored within the GPS. All the GPS satellites transmit information indicating its current position and time and this is done at the same time. These signals, travelling at the speed of light, are picked up by the GPS at slightly different times given the position and distance of the satellite. The distance to the satellite is estimated based on the time it takes to receive the signal. When a GPS receives signals from at least three satellites it can accurately calculate its position. With a signal from a fourth satellite, it can calculate its height. The more the number of satellite signals a GPS picks up, the better will be the accuracy.

GPS receivers only receive signals, they do not transmit. They require a clear view of the sky, and thus work only outdoors. They often do not work well near tall buildings, mountain side or inside forested areas. You could say that the GPS needs to 'see' the satellite. The accuracy of a GPS depends on the type of receiver. A simple GPS has an accuracy of about 10 metres. There are GPS systems which can give accuracies to the centimeter!

Figure 4.2: Global Positioning System



- *The first GPS satellite was launched in 1978.*
- *The launch of all 24 satellites was achieved in 1994.*
- *Each satellite survives for about 10 years. Replacements are constantly being built and launched into orbit.*
- *A GPS satellite weighs approximately 900 kg and is about 17 feet across with the solar panels extended.*
- *There are some 2,500 satellites orbiting the earth*
- *There are over 8,000 foreign objects orbiting the earth consisting of items broken off from old satellites*

Make Your Own Maps !

Start with a simple task. Look at your class room and see if you can make a map of your room. Locate the benches, backboard, windows etc. You could use just the compass and the trundle wheel for this.

You can make a map of your house - start from the compound wall, locate the building, any special trees in your garden, water taps in the garden etc.

You can map just about any area that you want using a combination of compass, footsteps, trundle wheel etc. If your school has a dumpy level use that to look at heights. For example, where is the water tank for your area located? Use the different tools you have learnt to better understand any map that you see. And have fun while doing so!

Remember whatever map you choose to do, the same basic principles will always apply.
So grab you paper, pencil and compass and go map your areas of interest.

ACTIVITY SECTION

Activity 1 : Drawing your own world

Materials Required

- One large potato
- String
- Scale
- Sketch pens – 2 colours

Instructions

- Locate the north & south pole - this should be at the center of rotation for the axis of your world. Take the longest line of the potato for this.

- Locate the equator by taking several measurements of equal distance between the poles, marking each position and drawing a line to connect the marks. Use a piece of string and a scale to take your measurements. You should be able to draw a line going round the pota to in middle.

- Now we make the prime meridian by drawing a line from the north to south pole that intersects (or cuts) the equator at a right angle.

- Now use a different colour to construct the lines of latitude in the northern hemisphere at 15 degree intervals, measure the distance between the pole and equator at a specific position. It will be easiest if you take the measurement in millimeters as it will be easiest to divide (to the nearest compatible number) when using these smaller units. Divide this distance by 6 (6X15=90). Make FIVE marks at that measured interval to determine where you lines of latitude will fall. Remember the 6th mark is already made – this is at the north pole. Repeat the measurement and marking process at several positions around the potato, then connect the marks to form your lines of latitude.

- Repeat the process for the southern hemisphere.
- Construct your 180th meridian by finding the point exactly half way around your potato from the prime meridian.

- Constructing your lines of longitude is a bit more difficult because of the shape of the potato. You will be working with making your lines of longitude much closer together than your lines of latitude. First, construct these in the western hemisphere. Measure the distance between the prime meridian and 180th meridian. Divide this distance by twelve (12X15=180). Make eleven marks at equal intervals to mark equal distances between meridians. Repeat the measurement process at several positions along the length of the potato, then connect the marks to form the lines of longitude.

- Repeat the process for the eastern hemisphere

- Your potato world is now ready!

Activity 2: Understanding projections

We have learnt about projections in the previous manual. It is a function or transformation which relates coordinates of points on a curved surface to coordinates of points on a plane.

Materials Required

- One Ball
- Sketch pens
- Scale

Instructions

Draw your world on the ball
This is your world and you have to show us a map of it
Use the sketch pens to mark some locations on it
Mark the continents, the seas, roads, rivers - decide how much detail you want to show

Taking it to paper

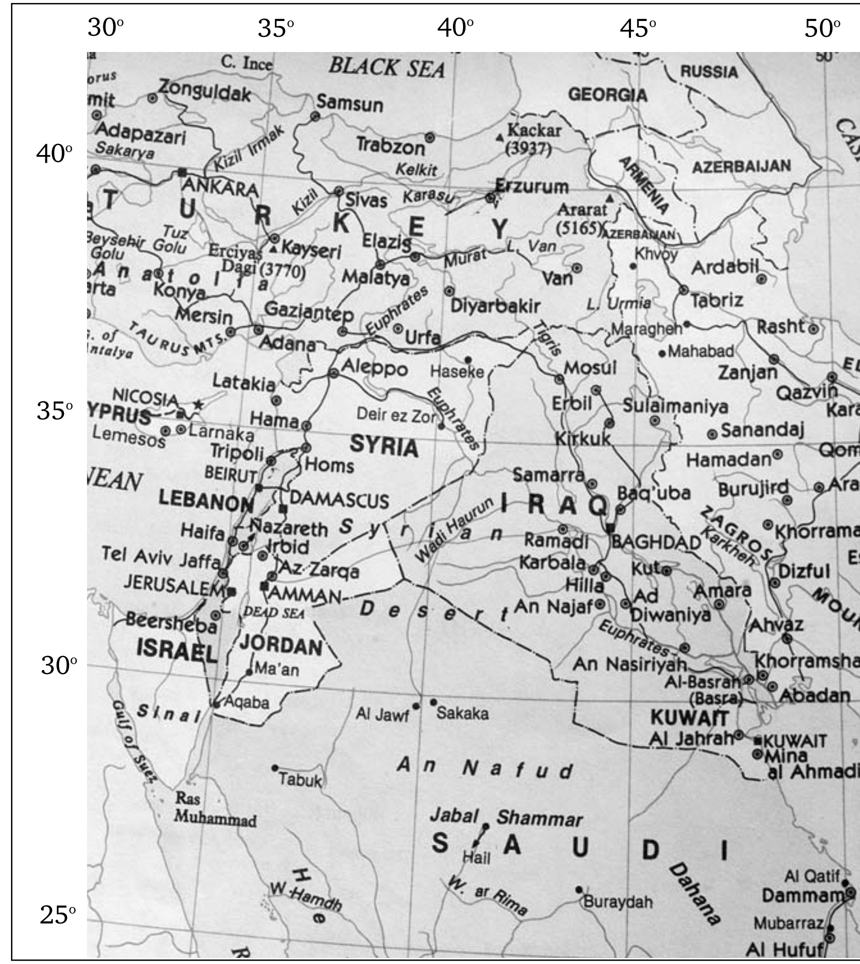
Make your world flat by taking out the air.
Cut the ball so that you are able to put it down flat on the ground

Discussion

What happens to your world when you try to make it flat
Do your continents, roads etc. look the same
How do you think we can we make this a flat map?

Activity 3: Find your spot

Look at the map provided and fill in the blanks below. Take the closet latitude and longitude values.



Sl No	Location	Longitude	Latitude
1	Ankara		
2	Beirut		
3	An Nasiriyah		
4	Zanjan		

Activity 4: Measurements and methods

The Trundle wheel

Architects probably used a device called the trundle wheel while building the Egyptian Pyramids. We commonly use a ruler, meter tape, known length of string, etc. to measure distances. But each of these requires us to make repeated measurements. Take one measure to the maximum possible, mark the spot, take a new measure from this and continue till the end is reached. Thus normally we would ned at least two persons for measuring a distance. The trundle wheel, however, relies on the simple fact that a circle with a known circumference can be used as a ruler. The circumference is the distance around any circle. Take a string one foot long and bring the ends together to form a circle -- the circumference of this circle is one foot. Rolling a circle with a known circumference along on its edge and counting how many times the circle can go around will tell you how many feet make up that distance you rolled it. So all you need to do is hold your trundle wheel to the ground and go for a walk!

Making your own Trundle Wheel

Materials: Big pieces of cardboard, scissors or blade, meter stick or scale with hole at one end, drawing pins or fevicol, dark colour marker pen, ruler, a drawing compass or string.

1. Making circles of different circumferences requires knowing the radii of the circles. The relation, Circumference = 2 p r is used. So calculate the radius for circles of 1, 3 and 10 feet. Measure the radius with the drawing compass or string. Place the compass pin end to the centre of the cardboard and swing the pencil around to outline the circle.

Circumference	Radius
1 foot	
3 feet	5.73 inches
10 feet	
18 feet	

2. Carefully cut out the circle with the scissors. With a dark marker, make one straight line connecting the centre to one edge of the circle. This will help you count how many circumferences the wheel has travelled.

3. To the centre of the circle in the compass pin hole, fasten one end of the meter stick or the cardboard strip with the drawing pin. Or you can use fevicol to attach the stick.

4. Repeat these steps to construct the other trundle wheels.

5. Start measuring by lining the marker line pointed down with the ground where you want to begin the measurement. Roll the wheel along, counting how many times the marker line hits the floor.

6. Practice measuring different distances - the size of the blackboard, the length of the classroom, the size of the playground, the height of your classmates. Compare these measurements with those with a meter scale or tape.

Discussion

Are the trundle wheels easier to use than the meter tapes or footstep counts? Are the measurements different? What happens at corners? What are the advantages and disadvantages of the trundle wheel? Can students think of other shapes which might be good measuring tools?

Activity 5: Find the co-ordinates and give the time

Longitude and Time

Am I late? What time is it? I have to be in school before 8:30 am! Questions and worries that are constantly with us. Time is something that we are aware of from morning to night. These words itself tell us about time. How is time calculated? Is it the same all over the world?

The concept of time is linked to the longitude. The time that we follow everyday : when to get up, go to school, eat our meal, sleep; is called ***Local Time***. This is measured in terms of the position of the sun relative to a location. When a longitude faces the sun directly, it is 12 noon. It is noon all along this line from north to south. For a long time each town and city set its own time. But this became a problem once travel by rail became popular. Getting out train timetables became very difficult. The idea of dividing the earth into time zones was proposed by a Canadian engineer and railway planner, Sir Sandford Fleming, in the late 1870s. Used by the railways initially, these were adopted as a world standard in 1884. As the earth rotates, the same longitude comes to face the sun again after 24 hours. There are totally 360 lines of longitude. Thus the earth rotates 360/24 or 15o each hour. Thus 24 time zones corresponding to these were marked

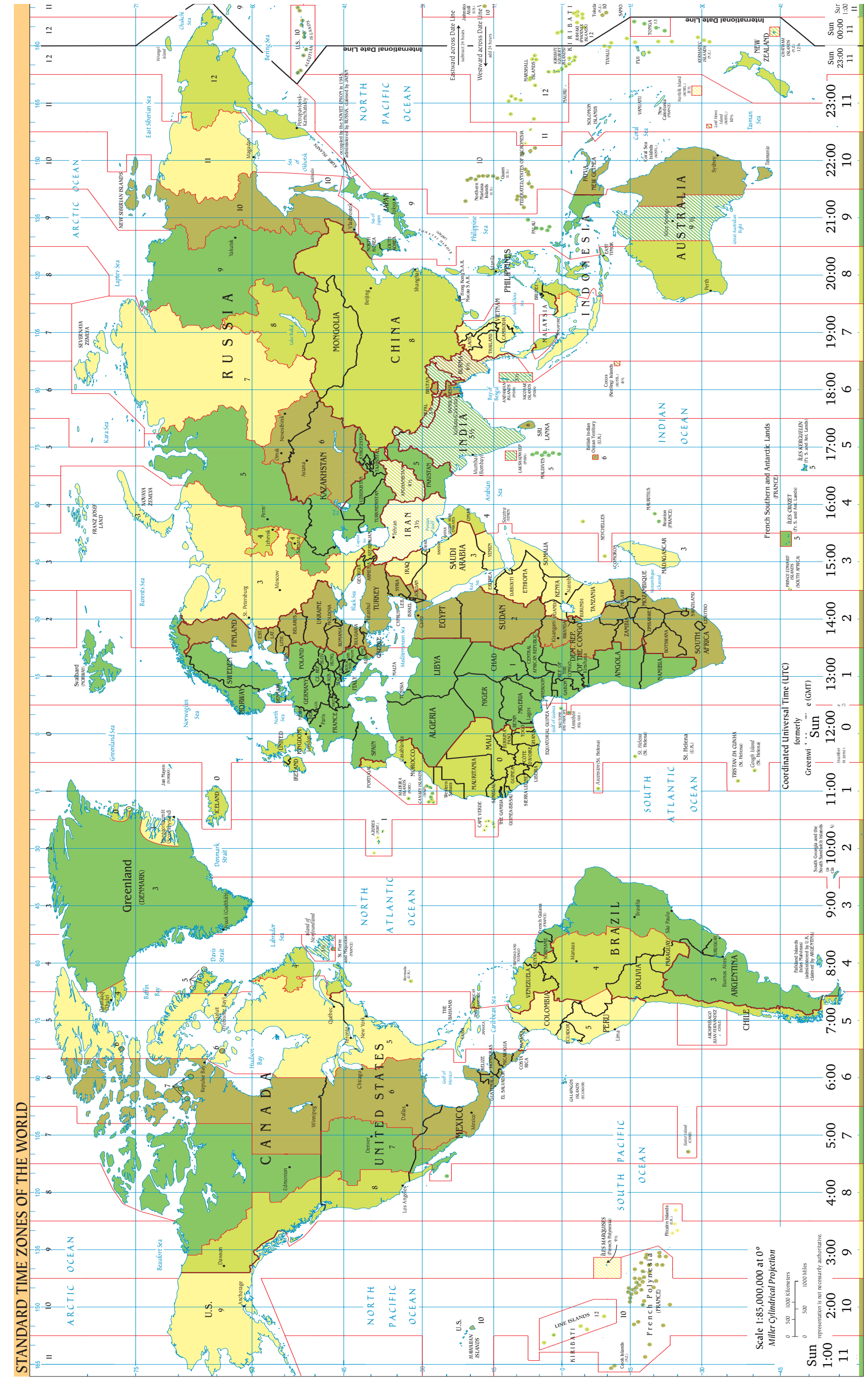
Q: Can you tell how many minutes apart is each longitude?

There is no clear indication for identifying the zero longitude as with the equator. That was easy, half way between the two poles is the zero latitude or equator. Until 1881, there were 14 different prime meridians (or zero longitude) that were being used on topographic survey maps alone. The International Meridian Conference of 1884 adopted the Prime Meridian as the line passing through the Greenwich Observatory near London, England. Since then, this has been our reference point for the zero longitude. We measure them from 0 to 180 in the East and 0 to 180 in the West, making a total of 360 longitude. It is also our reference for time calculations - the time along this longitude is known as the Universal Co-ordinated Time (UTC) or Greenwich Mean Time (GMT) and time is added to the east longitudes and subtracted to the west longitudes.

Q: How does the rotation of the earth influence time when compared across places? If the time along the zero longitude is 8:00 AM , can you calculate the time for the other places in the table below?

Place	Location	Time Difference*
Jakarta, Indonesia	6° 8" S; 106° 45" E	
Toronto, Canada	43° 40" N; 79° 22" W	
Chennai, India	11° 54" N; 79° 48" E	
Kathmandu, Nepal	27° 42" N; 85° 19" E	
Honolulu, Hawaii, USA	21° 19" N; 157° 50" W	
Moscow, Russia	55° 45' N; 37° 37' E	
Brisbane, Australia	27° 30' S; 153° 0' E	

* *calculate to the nearest longitude*



1 Fact File

Geodesy and Geodetic Control

Geodesy is "the science concerned with determining the size and shape of the Earth and the location of points upon its surface." Geodetic control refers to reference points on the earth whose exact positions are determined to a high degree of accuracy through measurement.

The earliest attempt at computing arc distance was by a Greek scholar Eratosthenes, in around 250 B.C. He computed the arc distance between Alexandria and Syene in Egypt by measuring the altitude of the noon sun at Alexandria on a summer solstice and assuring from a travellers' account that the sun is overhead at Syene. The estimated circumference of the earth by his method was 46,250 Km. or 28750 miles, which was only 15% larger to the present accepted value. After Eratosthenes, only in early 18th century, were attempts made to measure the arc of meridian. Some of the results of such attempts are given in the table below.

Meridional arc Measurements in 18th & 19th Centuries

Year	Observers	Country	Latitude of Middle arc O ' "	Length of one degree in	
				Kms	Miles
1738	Maupertius Re-examined by Svanberg	Lapland	1.31.08 N	111.49	69.28
	Struve	Russia	58.17.37 N	111.37	69.20
1802	Roy & Kater	England	52.35.45 N	111.24	69.12
	Lacaille	France	46. 52.2 N	111.21	69.10
1790	Delambre & Mecham	France	44.51.2 N	111.11	69.04
1755	Ruscovich	Rome	42.59.0 N	111.03	68.99
1750	Abbe Lacaille	Cape of Good Hope	33.18.30 S	110.87	68.89
1835	Everest	India	16.8.22 N	110.66	68.76
1808	Lambton	India	12.32.21 N	110.64	68.75
1735	Condamine & Bouguer	Peru	1.31.08 N	110.58	68.71

Source : The Great Trigonometric Survey of India, K. S. Sivasami, GIS@Development Sept 2000

Q Can you calculate the earth's circumference in kms or miles from the above table and see which is the estimate that is closest to today's accepted value of 39312.5 km or 24437.5 miles?

2 Fact File

The Great Trigonometric Survey of India

The trigonometric survey had its origin to an earlier related endeavour in measuring the arc of the meridian. The objective of the measurement of arc of a meridian was to determine the size of the earth. As survey methods became more accurate, the search for an exact calculation of the earth's size and attempts to calculate the exact position of locations became more common. The method of triangulation for survey was developed by General Watson in 1745. Such triangulation surveys were conducted in many places across the world. In India, such an attempt was started by Col. Lambton, Sir George Everest, Col. Waugh and Col. Walker were the persons who pursued the measurement of the great meridional arc from Kanyakumari to Banog in the foothills of the Himalayas and covering a large part of India by Trigonometric Survey from 1800 to 1866.

The administration however needed geographic information and small-scale maps for ruling and exploiting the country. For this purpose, in the 1820s Atlas of India project was established. The project aimed at compilation of maps at medium scale of four miles which "would bring together all the topographic surveys and warp them to fit GTS in order to create a definite cartographic representation of India"

Looking at the GTS, some 200 years after it was conceptualised and 135 years after its part completion, many interesting features can be found. The immediate task of the Great Trigonometrical Survey was the accurate determination of the position of important points over the country which would be the basis for geographical and other surveys and maps. Lambton also wanted to determine, by actual measurement, the magnitude and figure of the earth, a contribution to the geodetic science. He measured an arc of the meridian from Cape Comorin to 180 N, the longest geodetic arc ever measured so close to equator and he completed the results. Later Everest extended it up to Himalayas. These measurements did form the basis for the determination of the ellipsoids. The Everest spheroid is still used not only by India but also by Bangladesh, Bhutan, Burma, Nepal, Pakistan, Sri Lanka and other south-east Asian countries.

What is triangulation?

The endeavours in computing the distance of the arc of meridian in order to determine the size of the earth naturally led to the idea of providing accurate position of fixed points with reference to latitude and longitude which may provide landmark for accurate survey by method of triangulation. William Roy in the 18th century and Michael Topping were two of the early advocates of triangulation.

A triangulation may be simple in concept, but its implementation has always been difficult. It is slow and costly. The idea of a trigonometrical survey was first conceived by General Watson in 1745. William Roy determined the longitudinal difference by geodetic survey between the royal observatories of Greenwich and Paris.

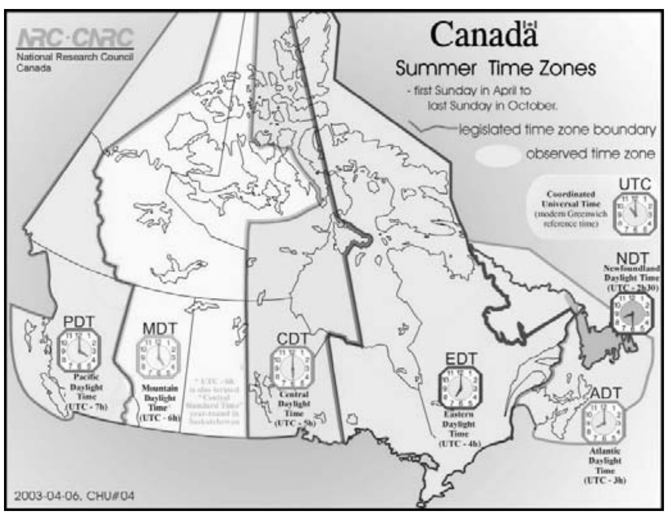
3 Fact File

Time Zones

Since the earth rotates 360 degrees every 24 hours, or 15 degrees every hour, it's divided into 24 time zones- 15 degrees of longitude each. When it is noon at Greenwich, it is 10:00 A.M. 30 degrees W., 6:00 A.M. 90 degrees W., and midnight at 180 degrees on the opposite side of the earth.

Countries with a large width, such as Russia (largest), followed by USA and then Canada, etc. follow time zones. For example, the Canadian mainland stretches from the Yukon-Alaska border at 141° 00' W longitude to Cape St. Charles, Labrador at 55° 37' W longitude. How many hours would this be? Thus the country is divided into strips which follow the time on a longitude central to that area.

Q What time do we follow in India? Can you look at the map of India and see what the time difference is between the eastern most part and the western most part of the country ?



Universal Time

Given that time varies across the earth, the concept of Universal Coordinated Time was introduced. This is defined as the local time at Greenwich, England, i.e. at the zero meridian. Thus any event that is relevant world-wide refers to the Universal Coordinated Time. Examples are launching of satellites, eclipses and other astronomical events.

4 Fact File

Date Line

Imagine you could travel with a snap of your fingers. If you started travelling from India at noon and went to Dubai, Egypt, London, Washington, Tokyo to .... and come back to where you started, what will be the time at these places? As you go west, you are moving to a time earlier than your own. Remember every 15o degrees you go west, it is one hour earlier. So when you reach 180o west, it should be 12 midnight and on reaching to where you started it should be 12 noon the day before! But this cannot happen. The problem is we have looked only at time and not date. The concept of date is fixed around the International Date Line (IDL) which is defined as the 180o meridian. This passes through the Bering Strait. When you go west of it, it is one day ahead or vice versa.

The only time the whole world is on the same date is when it is noon at Greenwich (0°) and midnight on the IDL (180°).

5 Fact File

Celestial Navigation

At any instant of time every celestial body (star) is directly above - or in the zenith of - some point on the earth's surface. This point lies on a line connecting the star and the center of the earth. It is called the geographical position or GP of the star. If you were standing on the earth, the line connection the center of the earth, through your position would cross the sky at a point. This is known as the zenith of the observer. The altitude of a star is the angle measured by an observer on earth between the star and the horizon. For eg. If the star was directly above the observer the angle to the horizon would be 90°. Or the observer is along the GP of the star. If he moved away a bit, then the altitude would be less than 90 by a an amount proportional to the distance. On the celestial sphere, this observer's zenith would be apart from the star by a distance called the zenith distance.

Read up and continue

The Nautical Almanac is a book of astronomical tables, which gives the position - for every second of every day - of the sun, the stars, the moon and the planets used in navigation. A navigator uses a sextant o carefully measure the angle to two stars and notes down the exact time. This time should be accurate to the second is taken from accurate clocks called chronometers. Now he consults the chart, draws out the lines. Were the observer a distance away from the GP of a star, the altitude of the star would be less than 90° by an amount proportional to the distance. On the celestial sphere, the observer's zenith would be apart from the star by a distance called the zenith distance or ZD.

All points a given ZD from a star would form around the star a circle of radius equal to the ZD. Were lines from all points on the circle extended to the center of the earth, a similar circle would be formed on the earth's surface. From any point on this circle, the observed altitude of the star would be the same; hence, it is called a circle of equal altitude. Its center is the GP of the star. A second circle of equal altitude would exist around the GP of a second star. Ordinarily, the circles would intersect in two widely separated points. One of these points would be the position of the observer on the surface of the earth.

SOLUTIONS

page 11; Figure 2.1 : Position D = 6, 9

page 12; On a graph sheet : Latitudes are on the Y axis and Longitudes are shown on the X axis.

Page 14; 85 degrees and 135 degrees.

Page 41; Activity 3 : Find your spot

Place	Longitude	Latitude
Ankara	33° E	40° N
Beirut	36° E	34° N
An Nasiriyah	46° E	31° N
Zanjan	48° E	36.5° N

Page 42; Activity 4 : Measurements and methods

a) Trundle wheel

Circumference	Radius
1	1.91 inches
3	5.73 inches
10	19.09 inches
18	34.36 inches

Page 44; Activity 5 : Longitude and Time

Each longitude is 4 minutes apart. The calculation is 15° = 1 hour so 1° = 60min/ 15 = 4min

If the time in Greenwich is 8:00 AM

Place	Location	Time Difference				As per Time Zone
		Num deg	x 4 min	hours	min	
Jakarta, Indonesia	6° 8' S; 106° 45' E	107	428	7	8	UTC+7 hours
Toronto, Canada	43° 40' N; 79° 22' W	79	316	5	16	UTC-5 hours
Chennai, India	13° 5' N; 80° 18' E	80	320	5	20	UTC+5:30 hours
Kathmandu, Nepal	27° 42' N; 85° 19' E	85	340	5	40	UTC+5:45 hours
Honolulu, Hawaii, USA	21° 19' N; 157° 50' W	156	624	10	24	UTC-10 hours
Moscow, Russia	55° 45' N; 37° 37' E	37	148	2	28	UTC+3 hours
Brisbane, Australia	27° 30' S; 153° 0' E	153	612	10	12	UTC+10 hours

Place	Time
Jakarta, Indonesia	3:00 PM
Toronto, Canada	3:00 AM
Chennai, India	1:30 PM
Kathmandu, Nepal	1:45 PM
Honolulu, Hawaii, USA	10:00 PM previous day
Moscow, Russia	11:00 AM
Brisbane, Australia	6:00 PM

Page 46 : Fact File 1 - Geodesy
Calculations of Earth's Circumference

Year		1735
Observers		Condamine & Bouguer
Country		Peru
Latitude of Middle arc O ' "		1.31.08 N
Length of a degree In	Kms	110.58
	Miles	68.71
Calculated Circumference (x 360 degrees)	Kms	39808.8
	Miles	24735.6
Earth's Actual Circumference in	Kms	39312.5
	Miles	24437.5
Difference from Accepted Value	Kms	496.3
	Miles	298.1

Page 48 : Fact File 3 Time Zones
The east to west extent of India is over 2,000 km from 68° 7' E to 97° 25' E. The Indian Standard Time is calculated on the basis of 82.5 °E longitude which is just west of the town of Mirzapur, near Allahabad in the state of Uttar Pradesh.

Eastern most point: Kibithu, Arunachal Pradesh
Western Most point: Guhar Mota, Gujarat
Time Difference between these two places is approx. 2 hours.