Emergency Land Navigation

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Introduction

Advancements in navigational technology have made finding way much easier than before. Nowadays, all kinds of navigational equipment are available, from the basic compass, map, sextant and almanacs to the highly efficient radars and GPS devices.

Although technology brings about convenience and precision, it may not be reliable at all times. Sophiscated equipments often tend to fail us when is insufficient battery power or when breakdown simply occurs. Furthermore, for amateurs like us or even to trekkers and campers, some of these expensive high-end equipments may be too bulky and heavy to be carried around.

As such, there is a need to know the basic methods of navigation as it allows us to have something to fall back on when everything else fails. Our project '*Emergency Land Navigation*' explores the many ways of contingency navigation with limited or makeshift instruments on land. In this case, the word emergency does not necessarily imply times of danger or crisis. In fact, such navigational methods and techniques are applicable anytime, anywhere.

Basically, *Emergency Land Navigation* deals with using approximations, techniques and simple knowledge of the environment to aid an individual in finding his way or to locate his position. This project targets land navigation instead of nautical navigation because we felt that the former was less touched on by books and websites. This observation was confirmed during our research process.

This project adopts an instructional approach, such that it introduces the various methods and techniques clearly in a step-by-step manner. At the same time, there are simple explanations and elaborations on how the methods are carried out. Most importantly, the concepts behind these methods are highlighted and explained. This project also includes an instructional video clip, which demonstrates some of the improvised methods of navigation that are mentioned in some of the chapters.

Eventually, we hope that this project will build up a reader's confidence in his basic navigational skills on land

Chapter 1

Basic understanding of Celestial and Terrestrial Terms

The Earth has 3 reference markers, the geographic *North Pole*, the geographic *South Pole* and the *Equato***r**. As we know that Earth is rotating and revolving about its oblique axis, we thus refer the North Pole and South Pole as the points where the axis cuts the sphere's surface. The Equator is thus conveniently selected to be the region mid point of these two poles.

The magnetic Poles are positioned slightly away from the geographic Poles. Since Earth's interior is a natural magnet, thus we can use the compass to determine our *Magnetic North* and *South*. After which, we can deduce the geographic North and South with some basic calculations, from the information taken from maps and charts.

Just like a map with grid coordinates, we have conveniently chosen to define positions on Earth surface using *latitude* and *longitude*. Since Earth is spherical, it will not be easy defining positions using just X and Y-axis, thus we define latitude and longitude in terms of angle with respect to a certain plane.

Using these reference markers and the coordinate system, we can now navigate our way and locate our position on Earth's surface. Projecting Earth's sphere, to a larger outer sphere, we have the *Celestial Sphere***.** The Celestial sphere is just a spherical wallpaper of stars to the Earth. It contains the *Celestial North Pole*, *Celestial South Pole* and the *Celestial Equator*. The Celestial sphere will be explained further in later chapters.

1.1 What is Latitude and Longitude?

Imagine that Earth's surface is covered with imaginary lines called Parallels and Meridians (Figure 1-1). Using these lines, we form a grid, which enables us to use a set of coordinates, Latitude and Longitude to describe any position on Earth.

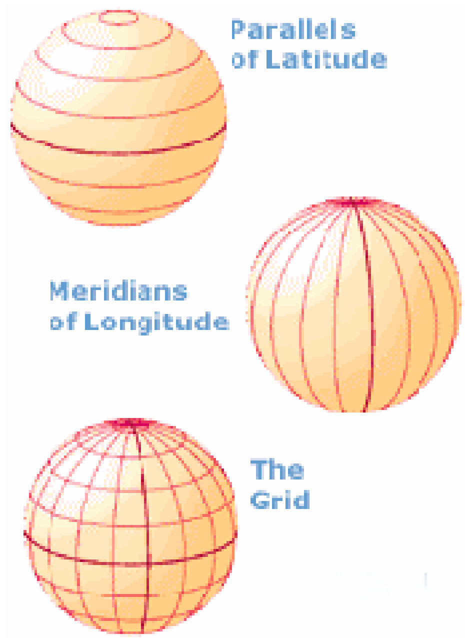

Figure 1-1

1.1.1 Defining Latitudes

Latitude, like Longitude is measured in degrees and since the Equator is the natural division between the Northern and Southern Hemisphere, we define latitude with respect to the Equatorial reference plane (Figure 1-2).

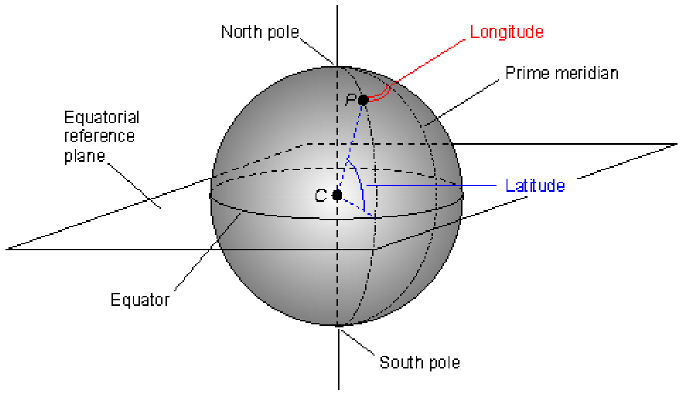

Figure 1-2

The Equatorial reference plane passes through the center of Earth; it contains the Great Circle representing the Equator (the biggest Parallel). From Figure 1-2, the latitude of the point P is defined as the angle that a straight line, passing through both P and C, the center of Earth, subtends with respect to the equatorial plane.

The Parallels of Latitude are each given a magnitude between 0 degrees and 90 degrees and a direction with respect to the Equator, either North or South. Latitudes of 90 (North) and 90 (South) degrees correspond to the North and South geographic poles on the earth, respectively.

1.1.2 Defining Longitudes

Longitude is defined in terms of its meridians, which are half-circles running from the North Pole to South Pole. The meridian passing through the Royal Greenwich Observatory in London was chosen to be our reference meridian or the prime meridian. For this reason, this meridian is also known as the Greenwich Meridian. From Figure 1-2, the longitude of the point P on the surface is defined as the angle that the plane containing the Meridian passing through P subtends with respect to the plane containing the Greenwich Meridian.

The Meridians of Longitude, just like Parallels, are also each given a magnitude and direction, except that for Meridians, the angle ranges from 0 to 180 degrees and falls either on the West or East Direction of the Greenwich Meridian. The 180 degrees West or East longitude meridians coincide directly opposite the prime meridian, at the International Dateline.

Since we know that Earth takes 24 hours to rotate a complete 360 degrees about its axis and that we know that the Meridians are lines joining the North and South Poles, we can deduce that we rotate 15 degrees longitude every hour.

Figure 1-3 *How the latitude and longitude at any one point on Earth is measured.*

1.2 What is a Celestial Sphere?

Imagine Earth as a perfect sphere; now imagine it being surrounded by another sphere, this outer sphere is clear and has stars printed on its wall. Celestial navigators know this outer sphere as a celestial sphere. The stars are fixed upon the sphere in relation to each other and thus are called fixed stars. Out of the many stars found on the sphere, there are only 57 of them, which we consider are bright enough to help us in our navigation.

Planets as a class move among the fixed stars; the navigational planets are Mercury, Venus, Mars, Jupiter, Saturn, the Moon and the Sun.

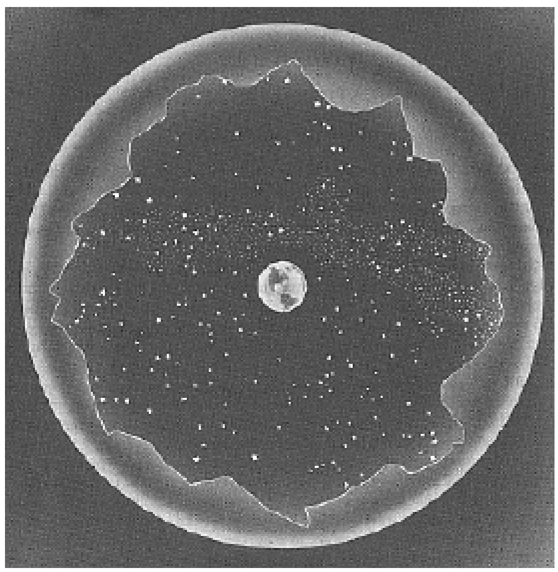

Figure 1-4 *Celestial sphere*

The apparent yearly path of the Sun through these stars is called the ecliptic. It is tilted 23.5 degrees with respect to the celestial equator. The Celestial Equator is just an imaginary circle around the Celestial Sphere above the Earth's Equator. The Celestial Equator lies midway between the North celestial pole and South celestial pole. These Celestial Poles lie just directly above the Earth's geographic poles on the celestial sphere, the North Celestial Pole above the Earth's North Pole and the South Celestial above the South Pole.

All the stars rotate in a path that is parallel to the celestial Equator.

1.3 Declination and Right Ascension

Extending Earth's latitude and longitude onto the celestial sphere, we have a coordinate system that uses declination and right ascension.

Declination and right ascension are used in the same way as latitude and longitude, except that the starting point for right ascension is not along Greenwich Meridian but it lies at the point where the celestial equator intersects the ecliptic, at the Vernal Equinox. Right ascension is measured in terms of hours, minutes and seconds instead of the usual degrees and the readings increase in an Easterly direction, with respect to the line joining up the starting point to the Celestial Poles.

With the use of Declination and Right Ascension, we can easily locate any stars on the Celestial Sphere.

1.4 Altitude of Celestial Bodies

Altitude is angular displacement and like latitude and longitude is measured in degrees. When measuring altitude of any celestial bodies, e.g. the Sun, the Moon and the stars, what we will be measuring angular displacement of the stars with respect to the observer's horizon. Altitudes are generally measured with equipments such as sextant and quadrants by the navigators.

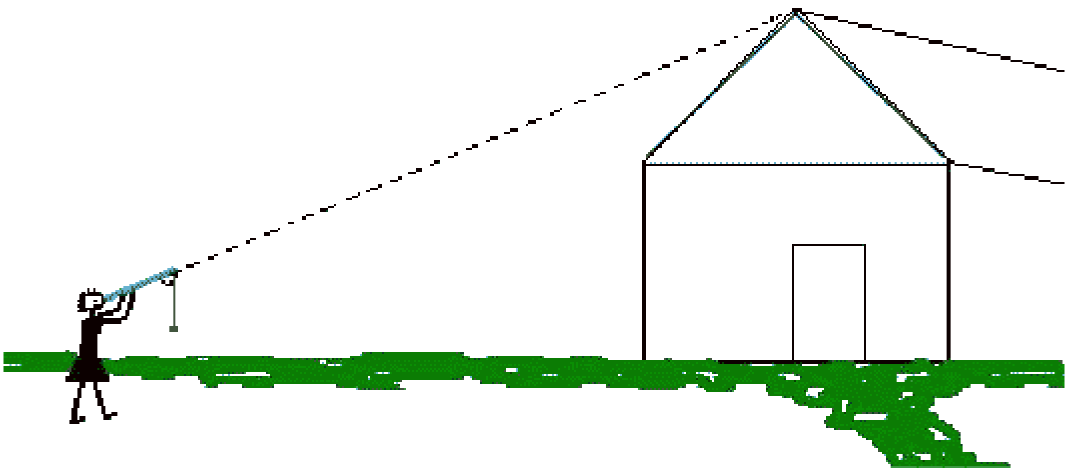

Figure 1-5 *How an observer measures the altitude of the tip of the roof*

Chapter 2

Navigation using Map and Compass

A compass is a simple navigational instrument that most people would carry with them when they travel. Similarly, it is very common for an individual to be in possession of a topographical map of the area that he is traveling in. As such, it is essential for everyone to know how to use the map and compass when needed.

This chapter aims to introduce the basic techniques of navigating by first focusing on the individual use and understanding of the topographical map, followed by the compass. The last part explains how to use the two items together for greater effectiveness and success.

2.1 Navigating with a Topographical Map

When travelling in unfamiliar terrain or when there are no visible landmarks to indicate the direction that you should go, it is useful to use basic navigation skills to continue. Below, we will be discussing on how to navigate with a topographical map.

2.1.1 What is a Topographical Map?

Maps are two dimensional representations of three dimensional features. The word MAP comes from the Latin word, *Mappa*, and it means napkin, cloth or sheet. The first map to represent the known world was created by Anaximander, a Greek philosopher in the 6th century BC.

Figure 2-1 A topographical map

Besides telling us where land features are and which way to reach them, a topographical map also describes the shape of the land. It defines and locates natural and manmade features like woodlands, waterways, important buildings, and bridges. In addition, it shows the distance between any two places and the direction from one point to another.

2.1.2 Using Contours

The topography and features of the land are easily shown by contours. Contours are imaginary (brown) lines that follow the ground surface at a constant elevation. They are usually marked with numbers that give the height in feet or meters. The contour interval is the difference in elevation between the brown lines and it varies from map to map; its value is given within the margin of each map.

Fig 2-2 shows the contour lines of a particular mountain. The close gathering of contour lines on the mountain represents a steep slope. The spread out contour lines indicate a gentler slope.

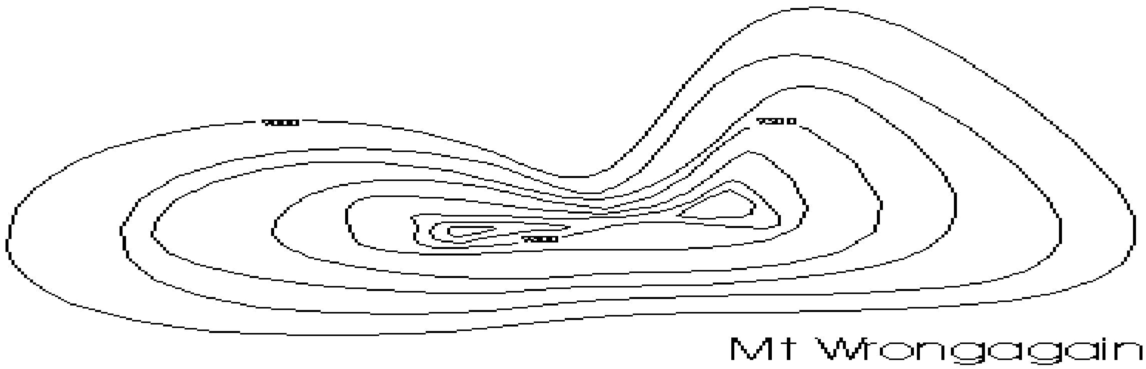

Figure 2-2 *An example of contours, extracted from a map of Mt. Wrongagain*

Using the above contour lines, we can imagine how the feature looks like.

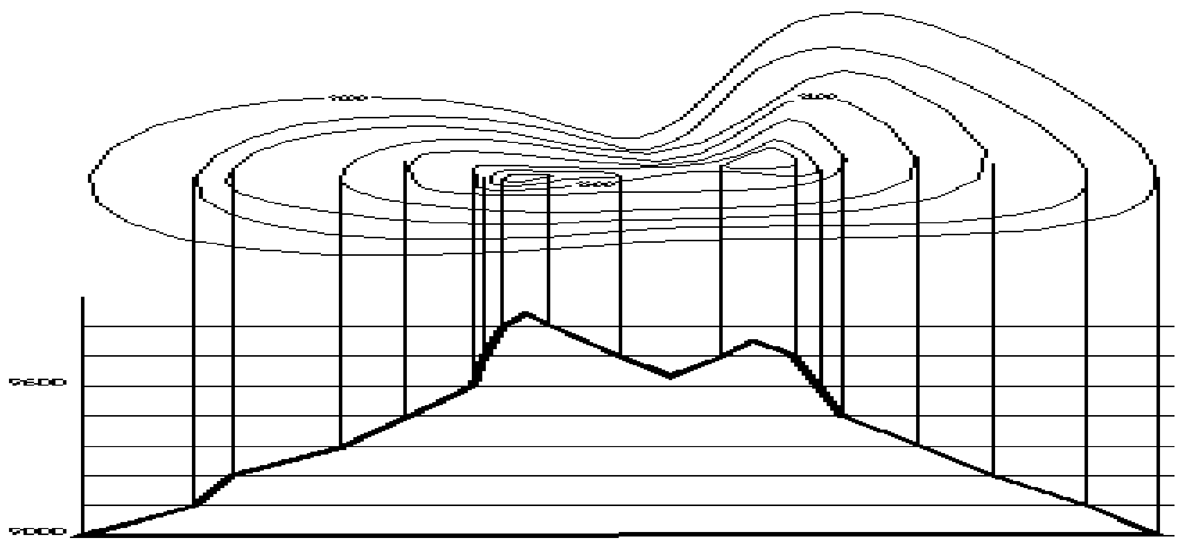

Figure 2-3 *Side View of Mt. Wrongagain*

In Figure 2-3, we can see that the mountain has two peaks, with the higher summit on the left. The lower slopes are moderate, and increasing in steepness towards the summits. When interpreting a contour map, it is necessary to take note of the elevation, ridges, and valleys. It is a fact that water always flows down through valleys or gullies, never ridges. Figure 2-4 shows a gully and ridges formed by contour lines.

Below are definitions of the terms mentioned earlier on:

Feature	Definition
Creeks:	A narrow inlet where the sea comes a long the way into the land.
Gully, valley, or bowl:	A long, narrow area of land between hills, often with a river flowing through it.
Ridge:	A long, narrow piece of raised land

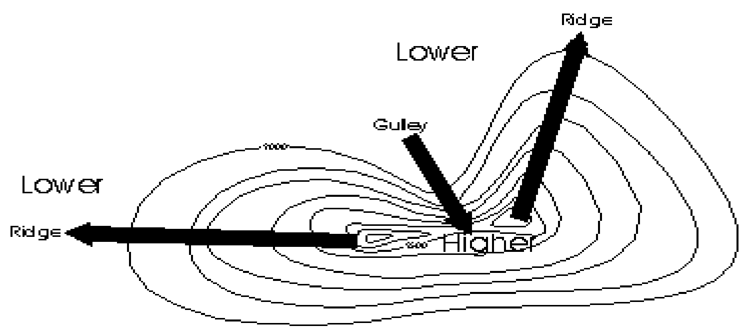

Figure 2-4 Gulley and ridge

2.1.3 Using Scale

Scale is the ratio between a unit of measurement on the map and the actual distance that the same unit of measurement represents on the ground. It is a representation of the size of a feature on the map relative to the size of the real thing.

For example, a river measuring 1 centimetre on a map with a scale of 1 to 50,000, would represent an actual lake that is 0.5 kilometres wide. A stream 2 ½ thumb nails long on a 1:100,000 scale map would represent an actual stream 250,000 thumb nails long.

2.1.4 Using Map Coordinates (Grid system)

On the map, there are two sets of parallel (black) lines which mark the grid lines. These lines run vertically and horizontally on the map. They represent a certain distance and enable people to accurately specific a position of a place.

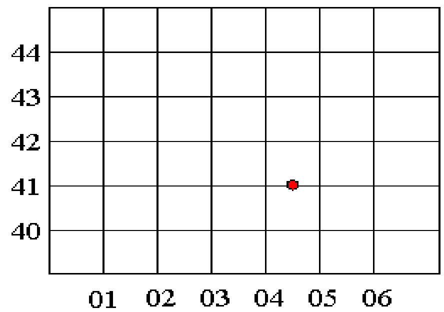

Figure 2-5 *Map Coordinates*

The set of numbers on the left and right side of a map that digit each of the horizontal grid lines are known as Northings. The other set of numbers on the top and bottom of the map that digit each of the vertical grid lines are known as Eastings.

To find the grid coordinates of a location, we need to know how to use the Eastings and Northings:

Instructions:

1. First, follow the vertical line to the left of the chosen location down to the foot of the map to read it's Easting - for example 04
2. Estimate the number of tenths from the same line to the location. Assume it is 5 in this case. Therefore the first part of the grid reference is 045. (Figure 2-5). However, if the location happens to coincide with the vertical line, the full Eastings can be found by adding a zero. E.g. 040.
3. Repeat this with the horizontal grid line just below the location.

   Since the location coincides with the Northings (41), the second part of the grid reference is 410.

4. Hence the full six figure grid reference, in this case, is 045410.

2.1.5 Using Map Symbols

Natural and man-made features are represented by colored areas and by a set of standard symbols on all topographic maps. Normally,

- Woodlands are shown in a green tint.
- Waterways are shown in blue.
- Buildings are shown on the map as black squares or outlines.
- Recent changes in an area are shown by a purple overprint.
- Road are printed in red or black solid or dashed lines, depending on its size and surface.

Some symbols of common roads and paths seen on the map are shown below.

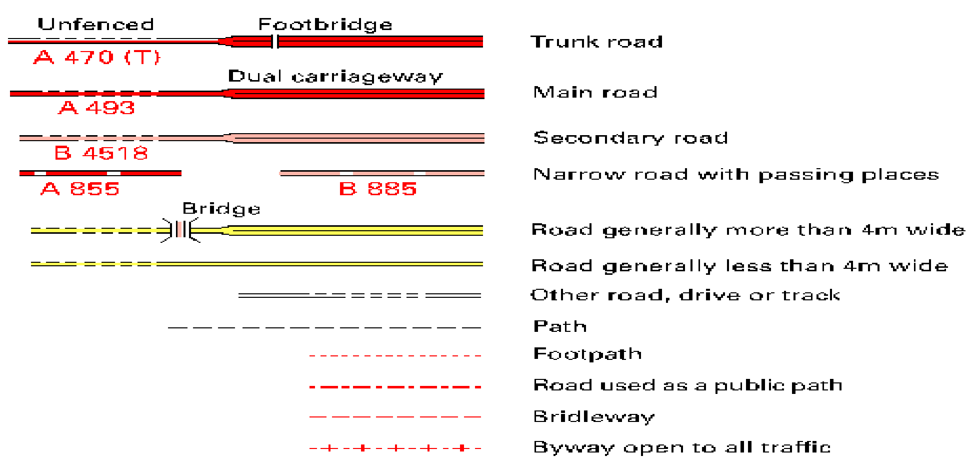

Figure 2-6 *Common road symbols*

2.1.6 Lost with a Map

When a person is lost and the map is the only basic item that he has, these are the steps that he must do to find his location.

Instructions:

1. Estimate the distance that you may have travelled from the last reference point
2. Mark this as a circle from that point on the map. It is reasonable to assume that you are somewhere in this circle.
3. Read the contours within the circle and eliminate the places that you cannot be. (glaciers, lakes, cliffs, etc.).
4. Look at the possible areas that you can be. Are there any large terrain features indicated on the map that you can travel to from all your possible locations (such as large lakes, roads, well defined trails, railroad tracks, power lines, rivers, etc.)?
5. Choose the most reasonable terrain feature. Take a general direction and begin moving towards it.
6. Let's say you picked a river. When you reach it, look around to see if there are any reference points to verify your location on the map, if there are, you are no longer lost. However, if there are no other reference points, look at the map and look for stream confluences, large bends, cliff banks, any unique features along the river.
7. Decide whether it is better to go upstream or downstream to find a reference point. Eventually, you will find a reference point and know where you are.

2.2 Navigating with a Compass

Navigating with a compass is important as it not only tell you the four general directions (North, South, West and East) but also the bearing of a particular feature or landmark which you would like to go.

2.2.1 Principle behind the North-Seeking Needle in the Compass

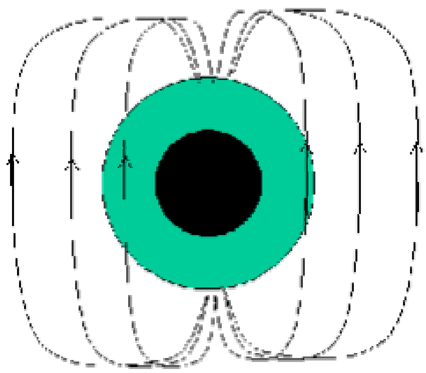

Figure 2-7 *Earth's magnetic field*

Inside the earth is a big magnet, which produces a magnetic field. The lines of the magnetic field all point in one direction, as shown in Figure 2-7.

Inside a compass, there is a small magnet attached to a needle. The magnet of the needle will be attracted to the magnetism produced by the Earth. Since the magnetic lines always point in one direction, the compass needle will also point in one direction, indicating where the North Pole is.

2.2.2 Part of a Base-plate Compass

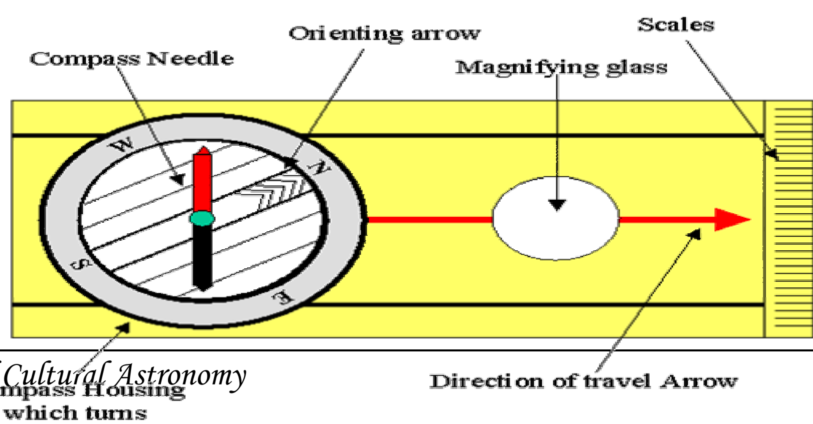

Figure 2-8 *Base-plate compass*

Before we learn how to use the compass, we need to know the various parts.

Parts of a Base-plate compass	Description
Compass Needle	This always point to the magnetic North Pole.
Compass Housing	This can be turned from the base of the unit. On the housing will be marked the letters N, S, E and W for North, South, East and West. Other type of housing may show numbers instead. This is a scale from 0 to 360 and represents the degrees around a circle.
Orienting Arrow	A part of the compass housing which turns with the housing. Along with the lines of the base of the compass, they enable you to set a map.
Magnifying glass	Enlarges details that are hard to be seen.
Direction of travel arrow	If you set a bearing, then follow this arrow for the direction.
Scales	In Fig 2-8, the scales are shown on the front of the compass. It is to take measurements from maps of the distance between two points.

2.2.3 How to Reach a Reference Point Using a Compass

When travelling to your reference point, you may lose sight of it easily. Hence, you need to know how to ensure that you are always on the right track towards the destination. The following steps will help you in doing so.

Instructions:

1. Hold the compass flat, otherwise the needle will touch the bottom or top of the housing and affect its north-seeking function.
2. Point the compass base (direction of travel arrow) to the object you wish to go to.
3. Keeping the compass pointing in the correct direction and flat turn the housing until the orienting arrow in underneath the RED end of the Needle.
4. Look at the number on the compass housing where it touches the direction of travel arrow. This number is the bearing to your destination.
5. Follow the direction of travel arrow, keeping the RED end of the needle over the orienting arrow. Keep looking at the compass every 50 - 100 meters, it should get you to your destination.

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2.2.4 How to Proceed in a Specific Direction

The following steps will help you to go in a specific direction.

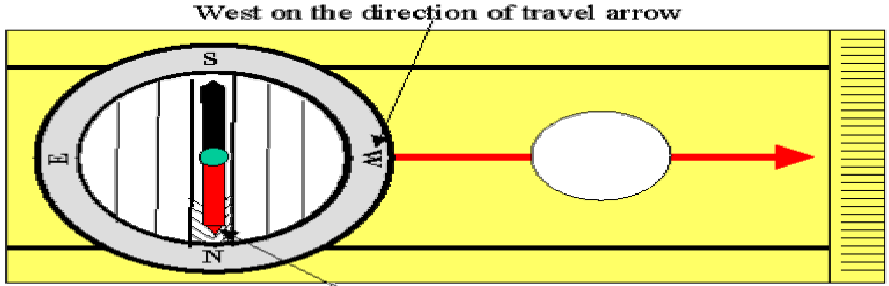


Figure 2-9

Instructions:

1. Imagine that you need to go west from your present location.
2. Turn the compass housing until the 'W' is over the top of the direction arrow.
3. Turn the compass base (keeping it flat) until the red end of the needle is over the top of the orienting arrow.
4. As above, keeping the compass flat, follow the direction arrow.

So, if you want to go at a particular bearing, say 40 degrees, just turn the compass housing until the 40 degrees mark is over the top of the direction arrow and follows the rest of the procedure as indicated above.

2.2.5 The 3 Norths

There are three North Poles. True North, Magnetic North and Grid North. **True North** is the Geographical North Pole. **Grid North** is where all the grid lines of a map that point to. **Magnetic North** comes from the earth's magnetic field and it shift around a bit (variable location).

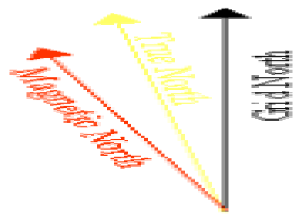


Figure 2-10 three Norths

When using a compass, it will indicate magnetic North. When you need to transfer a bearing from the compass to the map, you need to alter the bearing (number of degrees) to compensate for the difference. The magnitude of the difference will be determined by your location on Earth and the period of time you are in.(This will be explained later on)

2.3 Navigating with Map and Compass

2.3.1 Understanding Azimuths

An azimuth is defined as a horizontal angle measured clockwise from a north base line. This north base line could be true north, magnetic north, or grid north. The point from which the azimuth originates is the center of an imaginary circle and is divided into 360 degrees. Below is the figure showing an azimuth, take note of the base line and the angle, which is measured clockwise.

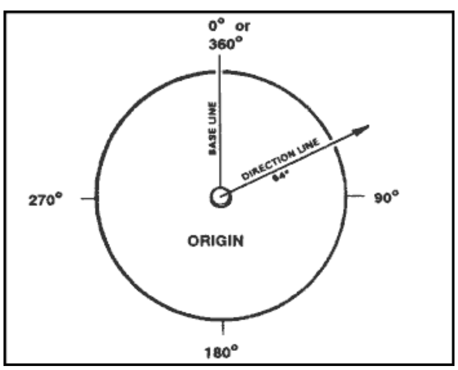


Figure 2-11 Finding Azimuth

2.3.2 Grid azimuth vs. Magnetic Azimuth

We plot an azimuth on a map between two points, point A (starting point) and point B (ending point), the points are joined together by a straight line. A protractor or a compass can be used to measure the angle between grid north or true North and the drawn line, and this measured azimuth is the grid azimuth.

The magnetic azimuth is determined by using magnetic instruments such as compasses and the base line for this azimuth is the magnetic North.

2.3.3 To Convert Grid North to Magnetic North and Vice Versa

A diagram at the map margin will show the difference of declination between the Grid North (True North) and the Magnetic or Compass North. G-M angle indicates the difference. It is important to understand how to convert Grid North to Magnetic North.

Figure 2-12 shows the Grid Azimuth is obtained using the declination and magnetic azimuth.

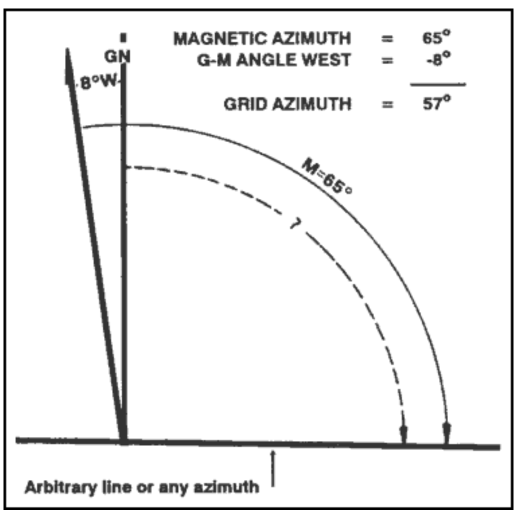


Figure 2-12 *How grid azimuth is calculated from magnetic azimuth.*

2.3.4 How to Locate your Position Using a Compass and a Map?

It is very important to locate your position. One of the ways is to use the Resection method

Instructions:

1. Find two visible reference points A and B on the map, example, a steep slope or a cliff.
2. Determine your compass bearing, the magnetic azimuth from your location to point A
3. Convert the magnetic azimuth to grid azimuth and draw a line to the point A using the angle.
4. Repeat the above steps for point B
5. The point of intersection of the 2 lines is the point where you are located.

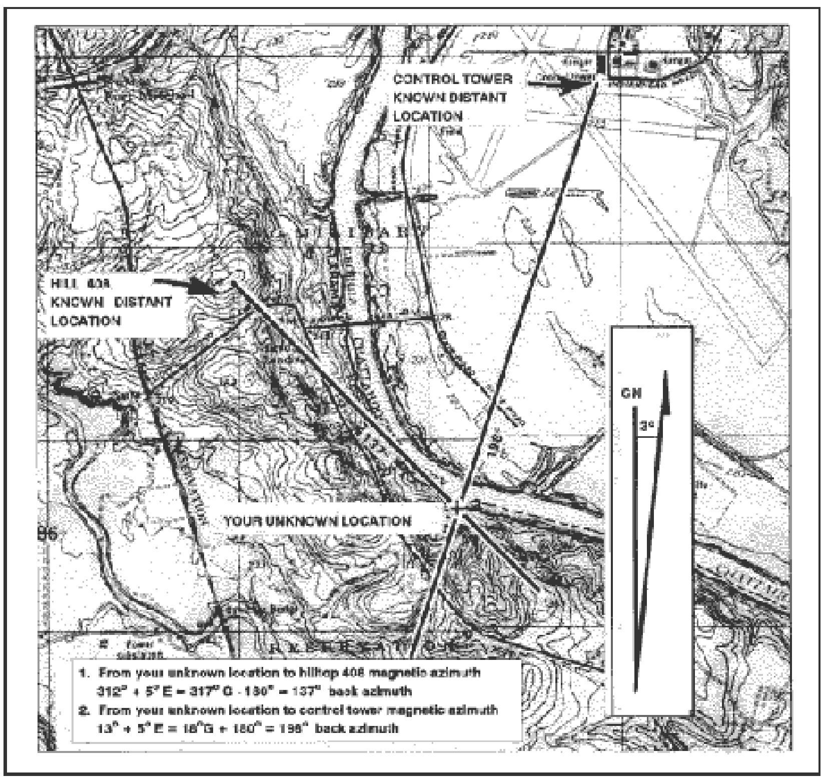


Figure 2-13 *Use of resection method to locate own position. The point of intersection of the 2 lines will indicate your position*

2.3.5 How to Get the Direction to your Destination?

Now that your position on your map is known, you can now locate your destination.

Instructions:

1. Draw a straight line from location C to the destination D.
2. Measure the grid azimuth using your compass or protractor.(Take note : the markings on the compass make it a good protractor)
3. Convert the grid azimuth to magnetic azimuth.
4. Use the magnetic azimuth and compass to find the direction of your destination

2.3.6 Finding Distance

Measure the line from point C and D on the map. Convert the length of the line to "actual distance" using the scale provided on the map. To find out whether we have reached our destination, we have to keep track of the distance we travelled. Below are the methods we can employ to help us find the distance traveled

a) Pacing

It measures distance by keeping track of the number of steps made. But it is only useful in temperate regions. In snowy areas, travelling by ski makes pacing difficult.

b) Estimation

Knowing the length time spent in the steady progress towards the destination, we can estimate the distance traveled. The figure below shows a rough estimation of the terrain and rate of travel for an average traveler.

Terrain	Rate of Travel
Gentle well maintained trails	4-5 kilometres per hour
Rough backcountry trails	3-4 kilometres per hour
Bushwhacking	2 kilometres per hour
Poor weather/whiteout conditions	2 kilometres per hour

For every 300m (1000 ft.) elevation gained	add 1 hour

Table 2-1 Rate of travel on various terrains

c) Field wire method

This method is only useful for ground distance measurements, in places where there are less slopes and hills. Two men will use a salvage field wire or rope of known length; let's take for example, 50 m. The lead man will walk, trailing the wire behind and once the rope is taunt, the second man will jerk the rope and tell the lead man to mark his position while he runs up to overtake the man until the rope is taunt. These steps are repeated till the destination is reached.

2.3.7 Reliability of Map and Compass

It is very important to take note that the use of compass is not completely reliable; the compass reading may be affected by the presence of iron or steel objects such as knife. The declination given by the map is also subjected to changes, as the magnetic North is constantly changing and the declination provided is the one measured during the making of the map.

Just like magnetic North, it is also important to note that features like small lakes, ponds and creeks may not be found in maps. The size and location of these waterways are subjected to changes, thus they may not be the same as the ones shown on the map.

Chapter 3

Improvised Navigation:
Observing the Sun

Finding our location on the Earth is very important. However, we always take our location for granted today because we have modern devices such as GPS to locate our position and navigate ourselves home. But what if we are lost in the wildness and these devices are not available to us?

Therefore, in a survival situation we must turn to the 3 things that our ancestors used - the sun, the moon and the stars. The sun is very important to our "sense of direction". In this chapter, we shall discuss how to find direction when the sun is shining, the old rule of thumb is that the sun rises in the East and sets In the West, and at midday in the Northern hemisphere will be roughly South. And also to locate our position (finding our latitude and longitude) using the sun.

3.1 Improvised Methods of Finding General Navigational Information From the Sun

This chapter provides step-by-step instructions on how to make simple apparatus to find direction and some other general navigation information such as time, altitude and also Local Apparent Noon from the sun. These apparatus are easy to make and use and most importantly, fairly accurate. This knowledge is definitely useful and essential especially when we do not have the aid of any comprehensive equipment, e.g. compass or map, in a time of emergency.

3.1.1 Finding Direction

To tell the direction, you have to watch how a shadow moves with respect to the sun.

a) Making a Sun Compass (Gnomon)

Materials:

1. A fairly straight stick, about 1 meter long
2. String or soft rope, about 1 ½ to 2 meters long
3. 3 fist-sized rocks

Instructions:

1. Push the stick into the ground so that it stands straight up; securely on its own.
2. Notice the shadow it casts on the ground and place a fist-sized rock on the ground at the top of the shadow.
3. Hold the end of the string at the base of the stick. Pull the string straight and hold the spot where it meets the rock. Now make an arc in the soil using the measured string length for the radius and the stick for the center point. Start at the rock, swing to the North and continue around to the East.
4. Come back to the project in a little less time than double the time which elapsed from the start to local noon. Keep an eye on the project until the top of the shadow meets the arc made earlier.
5. Place a second rock on the arc at the point where the shadow meets it.

6. Draw a straight line to bisect the two rock position on the arc. This is your East/West line.

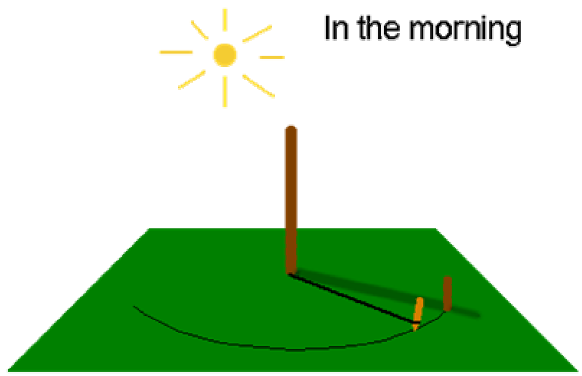


Figure 3-1

7. Draw a perpendicular line at the middle of your East/West line to obtain your North/South line.

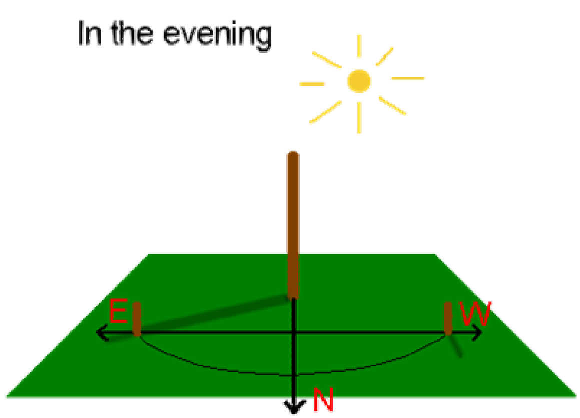


Figure 3-2

b) Navigating with a Hour-Hand Watch

Materials: 1. An analog watch

Instructions: *Northern Hemisphere:*

1. Hold the watch flat and point the hour hand towards the sun.
2. Bisect the angle between the hour hand and the figure 12 on your watch to give you the North-South line.
3. Another line can be drawn perpendicular to this one made it possible to determine North/South/East/West.

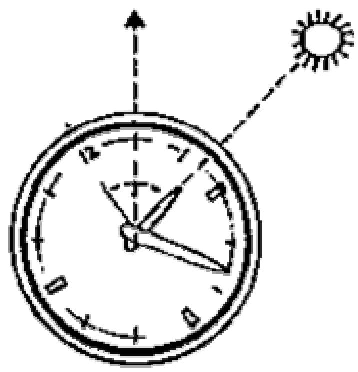


Figure 3-3

Southern Hemisphere:

1. Hold the watch dial and point the figure 12 towards the sun.
2. Bisects the angle between the hour hand and the figure 12 on your watch to give you the North-South line.
3. Another line can be drawn perpendicular to this one made it possible to determine North/South/East/West.

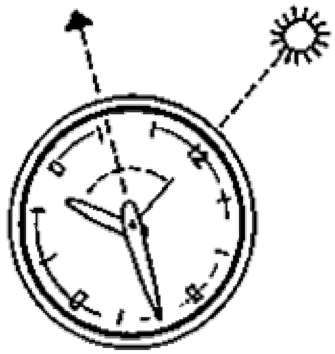


Figure 3-4

c) Using a Magnetized Needle

Materials:

1. 1 needle
2. Silk cloth or magnet
3. String
4. 1 piece of leaf or paper
5. A container/pool of water

Instructions: *Method 1*

1. Stroke the needle in one direction from its eye to its point with the scarf or magnet, about 24 times.

Figure 3-5

2. Suspend the needle by a thread half-way along its length and the point of the needle will point North.

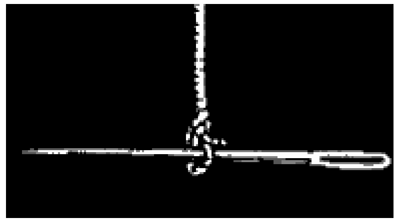


Figure 3-6

Method 2(the better way):

1. Stroke the needle in one direction from its eye to its point with the scarf or magnet, about 24 times.
2. Fill a container with water or find a stump with standing water in the center.
3. Laid the needle on a piece of leaf or paper and placed it into the water.
4. Allow the leaf/paper to stop moving, the point of the needle will point North.

Figure 3-7

3.1.2 Finding Time

a) Finding Time on your Hand

This method only can be used to find approximate time in the interval between 6am – 9 am or 3pm – 6 pm.

Materials:

1. Your hands
2. Pencil, pen or a straight stick of similar length

Instructions:

Part 1(Time from sunrise or sunset):

To ensure we are finding time inside the possible intervals,

1. Make fists with your hands. With arms outstretched (elbows straight), place one hand over the other, starting at the horizon to see how many "fist-widths" it takes to step your way to the bottom of the sun. Each fist-width is about 10 degrees (across your knuckles).
2. Since the sun (and all celestial bodies) moves across the sky at 15 degrees per hour, adjust the known sunrise or sunset time to the current time, based on how many fist-widths the sun is above the horizon. (1 1/2 fist-widths per hour). We are able to estimate whether we are inside the possible intervals to find our time.

Part 2(Time from shadow on your hand):

1. Hold a pencil or any straight stick with your thumb while your hand is pointing horizontally. The angle of the pencil should be as close as possible to your latitude. (Pencil point pointing approximately at the North Star).
2. Read the approximate time (refer to Figure 3-8 & 3-9).

(Morning - Hand pointing West, pencil pointing North)

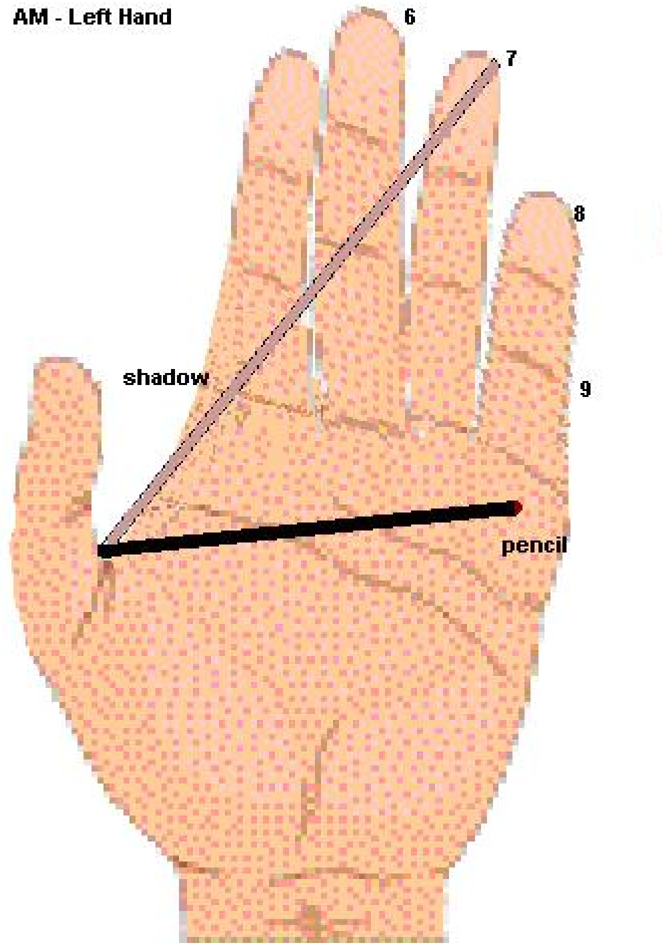


Figure 3-8 The shadow tells the time

(Afternoon - Hand pointing East, pencil pointing North)

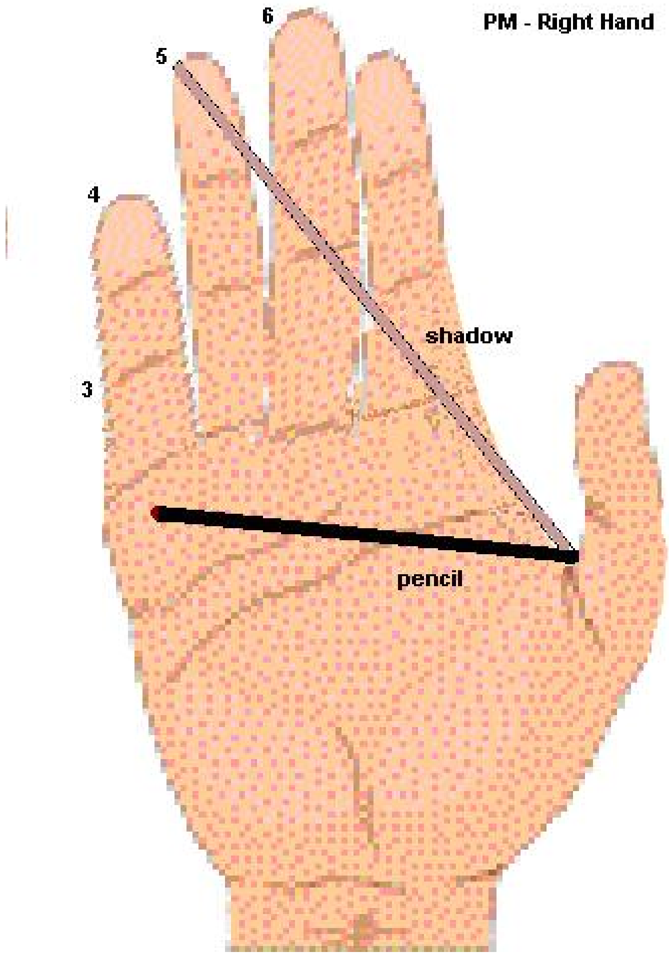


Figure 3-9 *The shadow tells the time.*

b) Making a Sundial Wristwatch

Materials:

1. Paper
2. Pencil or pen or any kind of writing material
3. Scissors and scotch tape

Instructions:

1. Draw out a watch face (as shown in Figure 3-10).

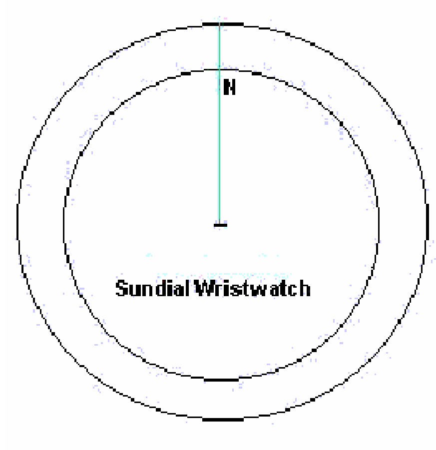


Figure 3-10

2. Use the blank face and make marks where the gnomon's shadow falls each hour.

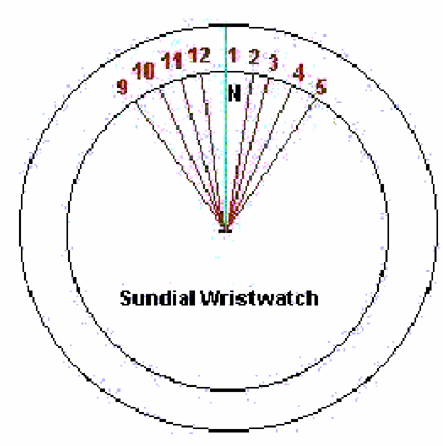


Figure 3-11

3. Cut out the watch face and gnomon for the latitude nearest your own and a wristband piece 2 or 3 cm wide (about 1 inch) and 1.5 times the circumference of your wrist.

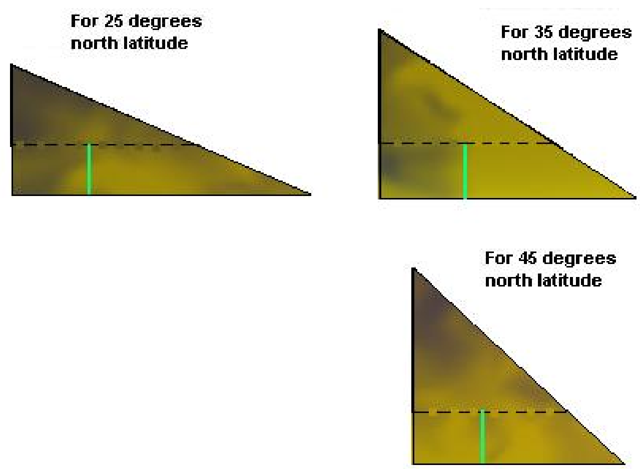


Figure 3-12 *Gnomon of our sundial - the part that makes a shadow on the watch face.*

4. Cut into the watch face and gnomon along the green lines (as shown in the Figure 3-10, 3-11, 3-12).
5. Fold the gnomon along the dashed line (as shown in the Figure 3-12).
6. Slide the gnomon onto the face's slit, folding the two underneath pieces to opposite sides. Make sure the side of the gnomon that is going straight up and down (vertical) is by the outer edge of the watch face.
7. Tape down the flaps under the watch face, trimming the extra from the flaps.

8. Tape the watch to the wristband with the vertical edge of the gnomon pointing toward the short side of the wrist band (see Figure 3-14).

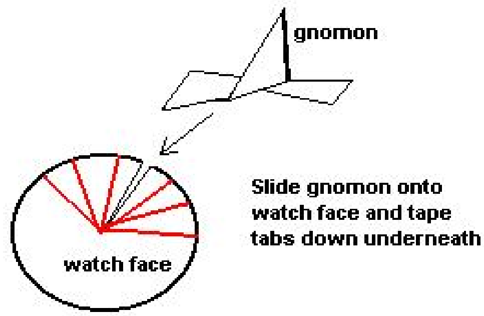
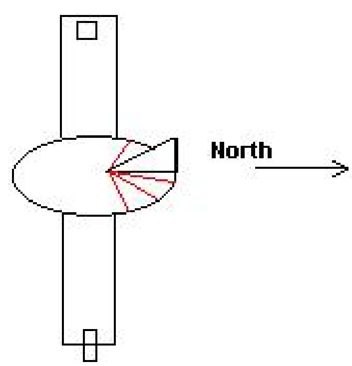


Figure 3-13

9. Put your sundial watch on your wrist and tape the ends together.
10. With the watch on your left arm, go outside and face West, holding your arm with the watch level in front of you so that the vertical edge of the gnomon is pointing North. (If you don't have a compass handy you can usually estimate North).
11. Read the approximate time by the number the shadow falls nearest to.



3.1.3 Finding Altitude (Quadrant)

Materials:

1. Paper
2. Pencil or pen or any kind of writing material
3. String
4. A piece of stone or plasticine

Instructions:

1. Making a scale for the quadrant. There are many ways to make the scale; we base our decision on what material is available. A protractor is most useful as the markings on it make an excellent scale. Alternatively we can cut a quarter out of a piece of circular paper and fold it to halves after halves, the creased lines after folding will make a rough scale for the quadrant. Then label the scale as follows:

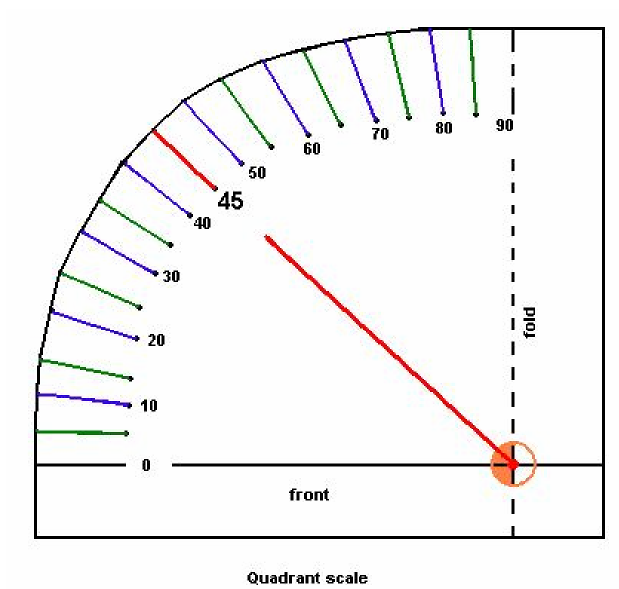


Figure 3-15

2. Tie a string attached to a small weight, either a stone or plasticine to the orange circle as indicated in Figure 3-15.
3. Attach a ruler or a long straight tree branch to the dotted line, a few centimeters away from its end. The circular edge faces the nearest end of the stick.
4. The altitude is measured by sighting an object along the stick, with one end touching your cheek bone (under your eye) and the other end pointing directly at the celestial body, of which the altitude you are measuring.
5. Make sure the string is touching the scale and "pointing down". Gently hold the portion of the string that is touching the scale.

Figure 3-16

3.1.4 Finding Local Apparent Sun

Materials:

1. fairly straight stick, about 1 meter long
2. string or soft rope, about 1 ½ to 2 meters long
3. fist-sized rocks

Instructions:

1. Just like making a Gnomon for finding direction. Push the stick into the ground so that it stands straight up; securely on its own.
2. Notice the shadow it casts on the ground and place a fist-sized rock on the ground at the Top of the shadow (this should be done in the before noon).
3. The time, t_1 should be noted at this moment.
4. Hold the end of the string at the base of the stick. Pull the string straight and hold the spot where it meets the rock. Now, make an arc in the soil using the measured string length for the radius and the stick for the center point. Start at the rock, swing to the North and continue around to the East.
5. Check on the setup around local noon time. Notice that the length of the shadow is the shortest at local noon.
6. Come back to the project in a little less time than double the time which elapsed from the start to local noon. Keep an eye on the project until the top of the shadow meets the arc made earlier.
7. Place a second rock on the arc at the point where the shadow meets it.
8. This second timing, t_2 should also be noted.
9. Local Apparent Noon would be the average time value of t_1 and t_2

Figure 3-17

In the example shown in Figure 3-17, point B is passed at 11 hours 15 minutes (t_1) and point A at 13 hours 15 minutes (t_2). Hence the LAN is at 12 hours 15 minutes.

3.2 Locating our Position

If you know your location on a map, then you are hardly lost. By observing the sun, you will be able to determine your latitude and longitude. After locating your position, you will then be able to navigate your way out of the wildness.

3.2.1 Finding Our Latitude:

There are several independent ways to find latitude without modern instruments, and the principles behind these methods are easy to understand and remember.

The Earth is round, but when you look off into a far distance, the horizon seems flat. That is because we are so small compared to the Earth, that we just can't see the curve. Similarly, the Earth is very small when compared to the Space. Thus, to make our navigation problem simpler, we assume the Earth to be flat right where we are standing and draw a straight line to represent our horizon and the atmospheric space around us is known as the Celestial Sphere. Figure 3-18 shows this idea.

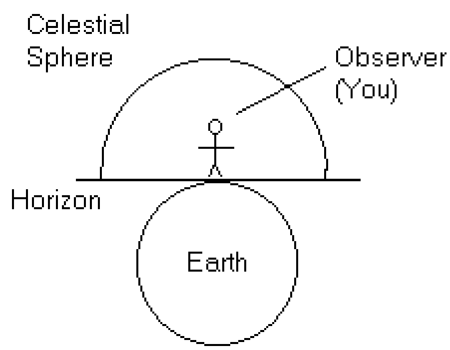


Figure 3-18

b) Altitude of the Sun

Now that we understand what is horizon and celestial sphere, we shall combine the horizon and celestial sphere idea with measuring the angle between the horizon and something in space to find the altitude of the sun (refer to 3.1.3 on how to find the altitude of the sun).

Figure 3-19 shows three observers; A, B and C, at different latitudes on the surface of the Earth. Assume that the sun is directly above the equator, but very far away. Imagine a line stretching from the center of the Earth to the center of the sun, passing through the equator. This line indicates 0° latitude.

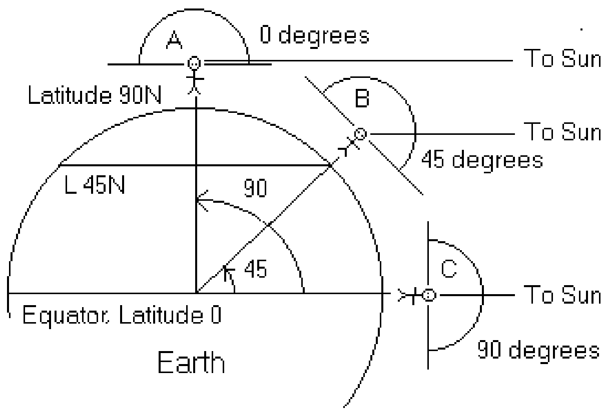


Figure 3-19

Therefore, to measure the altitude of the sun, the respective observer measures the angle from the horizon to the sun at their noon (LAN: Local Apparent Noon, noon at your exact location and when the sun is at its highest point in the sky; refer to 3.1.4 on how to find LAN).

From Figure 3-19, the sun is over the equator, thus the altitude of the sun for observer B (latitude 45° North) will be 45°. Observer A at the North Pole (latitude 90°N) will observe that the noon sun to be right on the horizon and thus he will observe the altitude of the sun to be 0°. Observer C at the equator (latitude 0°) will observe the noon sun directly overhead and thus altitude of the sun will be 90°.

c) Latitude Equation

As you move away from observer C on the equator, towards observer A at the North Pole, the latitude increases and the altitude of the sun decreases. Therefore to find our latitude, we take the complimentary angle of the sun's altitude:

L = 90° - Sun's Altitude

However, this simple relationship works only when the noon sun is directly over the equator, which happens only on 2 days of the year, March 21st and September 21st.

Thus for this equation to work for any sun position and therefore any date, we need to make a correction. We need to correct the result for when the sun is North (above), or South (below), of the equator.

d) Declination of the Sun

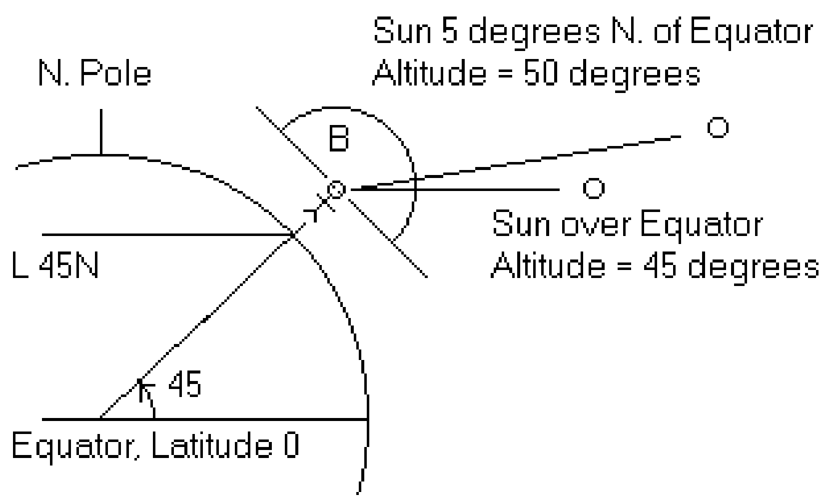


Figure 3-20

In Figure 3-20, the sun is shown 5 degrees north of the equator. The observed altitude of the sun is 50 degrees and we know from the sketch that the correct latitude is 45°N. But if we used the previous equation to calculate our latitude, we'll get 40°N:

L = 90° - Sun's Altitude
L = 90° - 50°
Latitude = 40°N

To correct this, we need to find out the declination of the sun, that is, if we add the number of degrees when the sun is North of the equator and subtract the number of degrees when the sun is South of the equator. Therefore to make our latitude equation works at any date, the declination of the sun has to be included:

L = 90° - Sun's Altitude + Declination of the Sun*

****Note: Northerly Declination is added, while Southerly Declination is subtracted. When Sun is over the Equator, Declination is 0.***

e) Determining Declination of the Sun at any Date

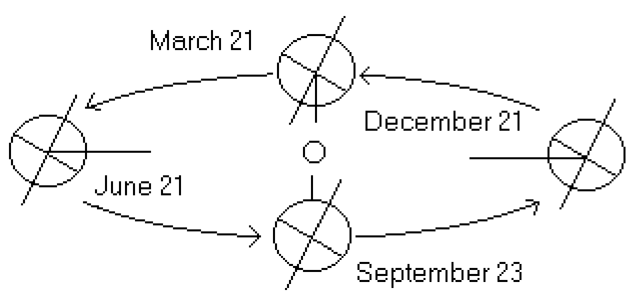


Figure 3-21

Figure 3-21 shows the Earth at four positions in its orbit around the sun. The sizes are enlarged to make it easier for you to see the details. The Earths are shown tilted 23.5° relative to a vertical line straight through the sun.

From the equator on the Earth at the June 21st position, we can see that the direction to the sun from that Earth shows the sun to be 23.5 ° North (above) of the equator. A similar observation of the December 21st Earth shows that the sun direction is now 23.5° South (below) of the equator. The remaining Earths at March 21st. and September 23rd. show the sun to appear directly above the equator. For Earth positions between the four shown, intermediate values are observed and we can predict the declination of the sun from this understanding.

Alternatively, we can find the declination of the sun from the Analemma (refer to Figure 3-22). The Analemma is printed on most globes, usually off the Ecuadorian Coast but always on the equator. This figure eight is a table of the declination of the sun and the Equation of Time. Ignore the time part for now and simply find the month you're looking for and pick off the number of degrees above or below the equator where that month is printed. If the sun is above the equator, it's called North Declination, if below the equator, South Declination.

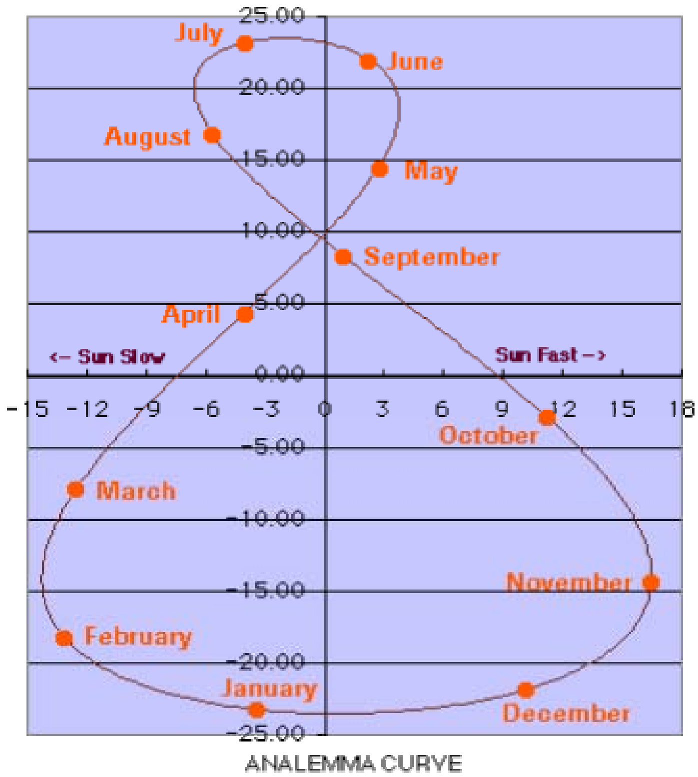


Figure 3-22

This chart shows the position of the true sun in the sky throughout the year. The y–axis on the chart represents the declination of the sun in the sky for one year, going from –23.45° in the winter to +23.45° in the summer. The x–axis represents the difference in time from what your watch reads to the actual position of the sun in the sky.

3.2.2 Finding our Longitude:

If only longitude can be determined, taken together with latitude, which is easy to find, these measurements allow locating of your position on the surface of the Earth.

To find longitude we have to understand 3 basic ideas: a) Time and Rotation of the Earth

b) Events and Time

c) Equation of Time

To find longitude we need to understand the relationship between time and the rotation of the Earth. For the Earth to rotate 360 degrees (so that a spot on its surface will move from under the sun and then return to its under-the-sun starting position), it takes an average time of 24 hours. The Earth will turn half around in 12 hours. A quarter in 6 hours. If you divide the number degrees in a circle by the number of hours in a day, we find that the Earth turns 15 degrees each hour.

360° ÷ 24 hours = 15° per hour

We can take this a step further and state that the Earth turns one degree in four minutes.

1 hour = 60 minutes ÷ 15° = 4 minutes per degree

To understand this second idea, we have to distinguish between events and time. To see how events and time fit together, imagine that you are watching your friends on a amusement ride that turns around and around. As you watch, two friends in separate cars pass you by. One after the other. Now imagine each friend has a stop watch, and they will start the watch just as they pass by you. The ride makes one complete turn, stops, and you collect the stop watches.

Clearly the first rider went by you earlier than the second rider. The event of passing you occurred earlier for the first rider. For the second rider, the event, passing you, was later. But when you check the stop watches, the time on the first rider's watch is later than the time on the second rider's watch. This is because the first rider's watch had started before the second's. Now imagine that you are actually the sun, the ride is really the surface of the Earth, and your two friends are actually two different places on the Earth.

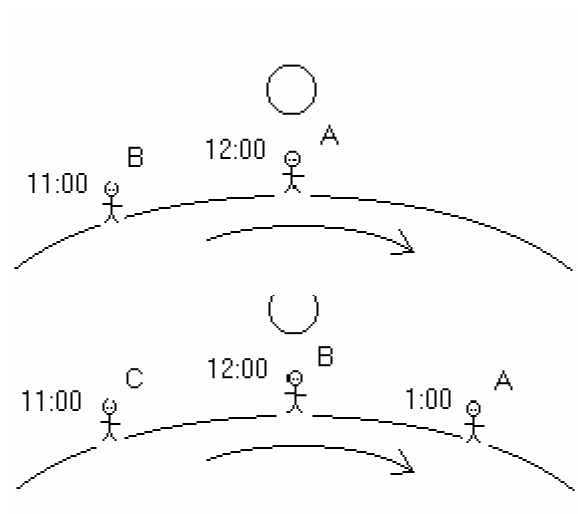


Figure 3-24

Observer A in Figure 3-23 observes Local Apparent Noon, which is simply noon for your exact location, and sets his watch to 12:00 based on Sun time. In Figure 3-24, we see that observer A has been moved eastward by the rotation of the Earth to be replaced by observer B. Observer B now observes Local Apparent Noon and sets his watch to 12:00 based on sun time. Observer C in Figure 3-24 will experience Local Apparent Noon latest of all and yet observer C has the earliest time.

And so it is that we have to be careful about the difference between the events and time. Events like sunrise in the east always happen before the same event in the west. But time as shown on eastern clocks is later than on western clocks at the same instant.

Local time earlier, position is Westward.
Local time later, position is Eastward.

If we combine the first and second ideas, we can find any longitude. Every point around the Earth has its own unique sun time. If you live one degree West (later events, earlier time) of me, your sun time would be four minutes earlier than mine.

The first idea, "Time and Rotation of the Earth" tells us that our time difference will be four minutes. The second idea, "Events and Time", tells us direction.

1 hour = 60 minutes ÷ 15° = 4 minutes per degree

c) Prime Meridian

In the example above, we compared our position to some other position. To this day, all longitude is figured from the line of longitude that runs through Greenwich, England. This is the line of zero longitude and is called the Prime Meridian. Lines of longitude are measured in degrees East and West from the Prime Meridian.

Therefore, we can find own position by observing the time and the height of the Sun at Local Apparent Noon. The height of the sun would tell us our latitude. The time of Local Apparent Noon, recorded as 12:00 local time, was compared to the time back in Greenwich as shown on the chronometer (a watch that keeps the Greenwich Mean Time) and the time difference will enable us to find our longitude.

d) Equation of Time

The difference in time between what your watch reads and the position of the sun (clock time vs. sun time) is called the Equation of Time. If you are in the Northern Hemisphere and the sun's position is to the East of where your watch indicates it would be, the Equation-of-Time is negative. If the sun is to the West, the Equation-of-Time is positive. We can also find our Equation of Time from the Analemma. The declination of the sun is shown above and below the equator, the Equation of Time is shown left and right (refer to Figure 3-22).

Figure 3-25

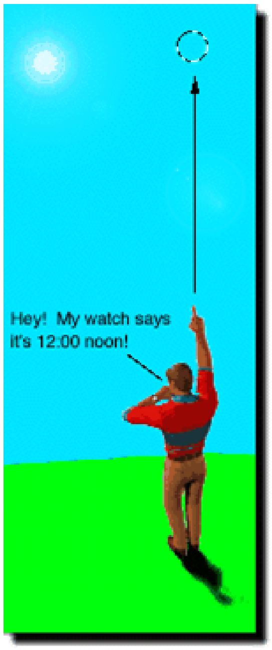


Figure 3-26

By applying the Equation of Time to the chronometer's clock time, we convert Greenwich Mean Time (Clock time) to Greenwich Apparent Time (Sun time) Greenwich Apparent Time, or GAT, is simply the sun time back at Greenwich, England. Now we can observe Local Apparent Noon and do our simple subtraction of GAT to find our longitude.

e) Finding Longitude

Once you've got the Equation of Time, you either add or subtract the value from your chronometer’s Greenwich Mean Time. The result is Greenwich Apparent Time, which is then compared to Local Apparent Noon. The larger value is subtracted off the smaller value. If your LAN is later than your GAT (Greenwich Apparent Time), then you must be to the east of the Prime Meridian. If your LAN is earlier than your GAT, then you must be to the west of the Prime Meridian. Then multiply the remainder hour part by

15° /hr and divide the remainder minute part by 4 minutes/hr. Add the 2 values and your longitude can be found.

Example:

8:32 GMT
- 0:08 Equation of Time

8:24 GAT

12:00 LAN
- 8:24 GAT

3:36

*3 hours * 15°/hour = 45°*
36 minutes ÷ 4 minutes/° = 9°
45° + 9° = 54°E

Chapter 4

Improvised Navigation: Observation of stars

At night, when out in the wilderness, without any proper navigational instruments, stars are extremely useful in determining general direction. Generally, finding directions from stars are far more accurate than using the sun or the moon. This is because stars require no seasonal correction factors like the sun does to accurately determine directions. In addition, by observing the rising or setting motion of stars, one could also find his own latitude on earth

In the hectic modern world that we live in, one that is polluted with bright lights and smog, most people know very little, or simply ignore the basic skills of finding directions from the stars. In ancient times, although man did not know what stars really were and how far away it is, they were able to identify them and their patterns to good use. This chapter would attempt to introduce the basic skills of improvised navigation by first briefly explaining what stars are, followed by instructions on how to identify the most common stars and constellations that we see above us.

4.1 Star Brightness and Magnitude

Basically, stars are classified according to the amount of light received from them. Each star is given a magnitude, or measure of its relative brightness. This scale was built on historical models from ancient Greece. The range of star magnitudes stretches from Magnitude 1 at the brightest to Magnitude 10, the faintest. Each whole number increase in the magnitude scale represents an increase in overall light energy of 2.5 times the next lower magnitude.

Stars of magnitude 6 are generally accepted as the very faintest magnitude visible to the naked eye. These stars could be seen only under the darkest and most ideal conditions, even in ancient times. In the 20th Century, a magnitude of 5.5 seems to be the extreme limit of visibility. With increased pollution levels in the 21st century, fewer stars would be available to us. For improvised navigation, most of the stars involved have magnitudes of about 2 and less as this would mean that they can be readily seen from anywhere at night.

4.2 Number of Visible Stars in the Night Sky

In suburban skies, only stars brighter than magnitude 4 or 4.5 are generally visible. There are fewer than 1,200 stars in the entire sky brighter than magnitude 4.5, of which approximately 500 are above the horizon at any one time. Of these 500, many will be so near the horizon that they are either not visible due to sunlight / sunset or are hidden by obstacles along the horizon. And out of the remainder of the stars visible to the naked eye, at any given time, a person can probably only see about 200-300 stars at any one time from home in a suburban environment.

At this point of time, it would be alarming for anyone navigating, to know that he would have to comprehend with so many stars in the sky. Luckily, that is not the case. What is mentioned above is indeed reality; but reality is only one part of the equation. This is due to the fact that because of the limits of our non-peripheral human vision, a person can probably only see only a few stars at any given time even under the best of conditions. Idealized images that we transmit into our heads influence our perception of reality.

Below is an example of a typical star chart of the Northern Hemisphere during winter period.

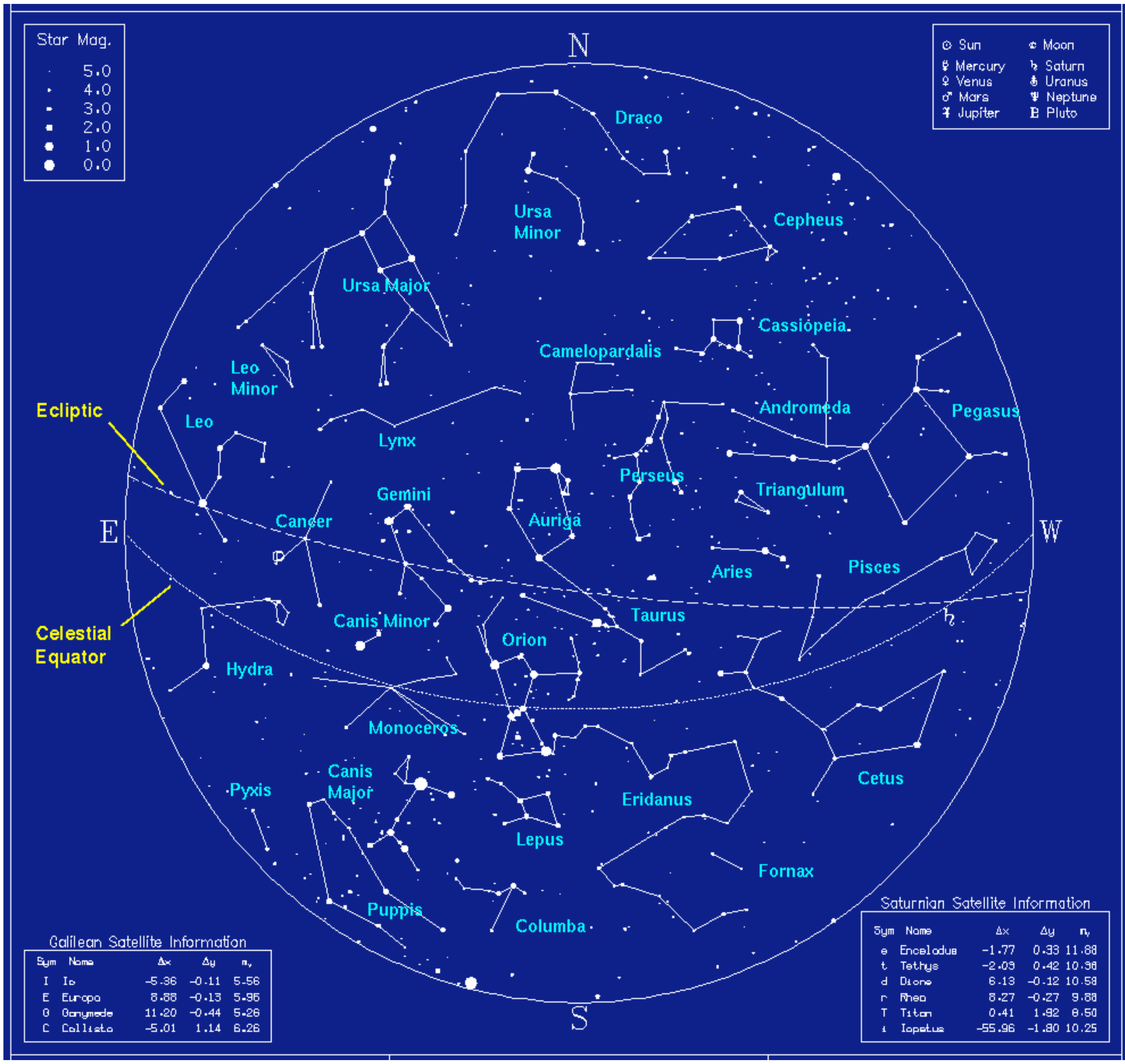


Figure 4-1 *Star Chart*

4.3 How to Differentiate Stars from Planets

For any observer looking up into the sky at night, one might be puzzled to find the majority of stars 'twinkling' while a few just seem to shine steadily. In truth, stars twinkle while Planets are the ones that shine steadily.

Star twinkling is caused by turbulence from the heating and cooling of gases in the atmosphere. The atmosphere bends the starlight passing through this turbulence. As the light passes through these gaseous "eddies", the intensity of a star's light varies slightly. Stars twinkle and planets do not because stars are so far away that they look like point sources of light even when viewed through large telescopes. Planets are close enough to earth that their images are tiny discs. As the light from each different part of a planet's disk twinkles, it averages out and makes the planet appear relatively steady to the human eye in both brightness and position. Also, planets are brighter and easier to spot.

In addition, when comparing the motion of the planets with stars, planets tend to move relative to stars on the celestial sphere in an apparent counter-clockwise movement.(when viewed from the northern hemisphere) The stars seemed to be fixed on the celestial sphere. By observing through long periods, this becomes very obvious.

Another observational difference through long periods is that planets are always near the imaginary yearly path of the sun on the celestial sphere while stars can be found anywhere on the celestial sphere.

4.4 Identifying Stars and Constellations in the Night Sky

It is very important for an observer to be able to identify some basic bright stars and key constellations. Remembering key constellations not only help in finding directions, they are also useful in a way that once an observer is able to do that, he would have no difficulty picking out most of the required navigational stars.

In fact, the greater the knowledge, the better it is since that would increase the chances of a person achieving his navigational aim. One must bear in mind that the ability to find directions from stars and constellations are greatly reduced when the sky is not cloudy.

Thus, the best bet would be to strive and achieve the essential skill of finding directions from patches of isolated stars.

4.5 Methods of Determining Direction using Stars

1. The *North Celestial Pole* (NCP) or *South Celestial Pole* (SCP) can be found by measurement from recognised star patterns. True North or True South is the point on the horizon directly below the respective Celestial Pole. The possible options to navigate this way are only limited by familiarity with the sky.
2. Observing the Apparent Motion of stars

4.5.1 Identifying North Celestial Pole using the North Star

Imagine you are standing on the equator. When you look straight up, you would see stars fly past you all night long as the Earth spins, sweeping you around the circumference of the Earth. The stars would appear to rise in the East and set in the West. However, if you were at the North Pole, it would look like the stars are spinning around a point straight up in the sky. This point is called the *North Celestial Pole*, and is basically the same as the North Pole on the Earth projected up into the sky. All the stars seem to spin around this point, just as the Earth spins around its own North Pole.

In the Northern Hemisphere, the star named Polaris or *Alpha Ursae Minoris* (its Bayer name), may be used to determine True North. Polaris is often known as the North Star due to its prominent position in the Northern Hemisphere.

The reason Polaris is important is because it is so close to the NCP. As the night progresses, Polaris does not rise or set, but seems to be glued to the sky! So at any time in the night you can find Polaris and it is always in the North. In fact, Polaris is excellent for locating the *North Celestial Pole* since its bearing is usually only 1 degree from true north and is never more than 2.5 degrees away.

In order to make use of this relatively bright star, it is essential to know how to find this star by identifying key constellations that are much easier to spot in the night sky. A few prominent constellations would be introduced below, highlighting their North Star pointers. North Star pointers are stars whose positions are depended on to locate Polaris. Hence even if Polaris couldn't be seen, a navigator could easily find True North by taking reference from these North Star pointers.

a) Finding Polaris using the Big Dipper

This star can be easily found by its position relative to the constellation known as Ursa Major (commonly known as the Big Dipper). As the name implies, it is a constellation comprising of stars that resembles a shape of a dipper in the sky. It is termed big due to its relative size to a smaller but similar shaped constellation near it.

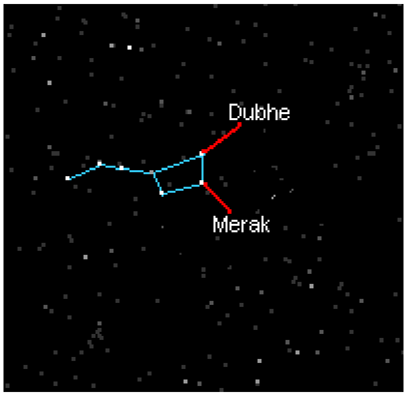


Figure 4-2 *Ursa Major*

Instructions:

7. Locate the Big Dipper and identify the the 2 stars at the forward tip. These two stars are Dubhe (*Alpha Ursae Majoris*) and Merak (*Beta Ursae Majoris*), which are located at the front tip and front base of the Big Dipper respectively.(Figure 4-2)
8. Extend a line from Merak through Dubhe for a distance of approximately 5 times of the distance between the 2 stars mentioned.(Figure 4-3) Alternatively, this line can be estimated by taking reference to the distance between Merak and Dubhe with your fingers. With your arms outstretched, if the distance between the 2 leading stars is 2 finger widths, than the distance from Dubhe to Polaris is about 10 finger widths.
9. At the end of the line found above, one should find a fairly bright star at the end called Polaris, the North Star.
10. Extend a line vertically down from Polaris to obtain a convenient and accurate location of *North Celestial Pole*.

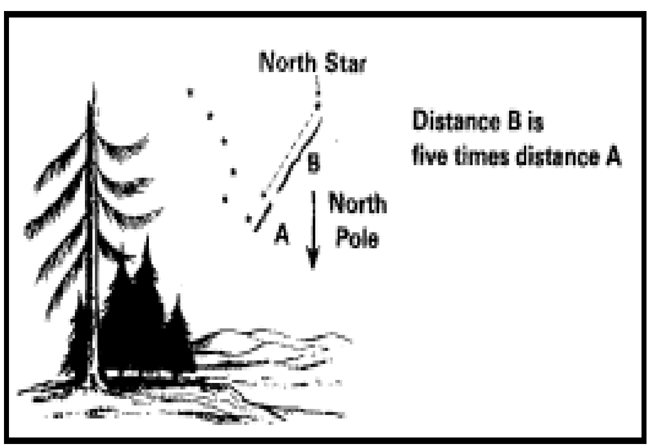


Figure 4-3 *Determining NCP using North Star and Big Dipper*

b) Finding Polaris using Cassiopeia

Another important key constellation that can be easily spotted in the Northern Hemisphere is Cassiopeia. Look up in the sky and search for 5 stars that resemble the shape of an 'M' or 'W', depending on where you stand. Normally, this constellation is found on the opposite side of the Big Dipper, with Polaris in between them. Hence, this constellation comes in handy for navigation when the Big Dipper is not visible.

The leading stars are much brighter than the trailing star. One of these stars is Caph (*Beta Cassiopeiae*). When compared, the trailing side of the letter seems to be more flattened out, even though the constellation seems symmetrical on the whole.

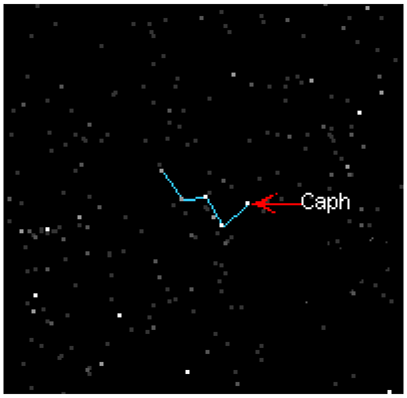


Figure 4-4 *Cassiopeia.*

Instructions:

1. Locate Cassiopeia and extend a line connecting the bottom 2 stars of the visible 'M'. (Or the top 2 stars of the 'W', whichever is applicable.) These 2 stars are the North Star pointers.
2. Estimate the distance of the line above and beginning from the star at the bottom right leg 'M' (Or top left leg of 'W'), extend another line that is perpendicular and twice the length of the 1st line found earlier on.
3. A fairly bright star found at the end of this 2nd line would be Polaris.

c) Finding Polaris using the Little Dipper

Polaris (*Alpha Ursae Minoris*) is actually a star that belongs to the constellation named Ursa Minor, or Little Dipper. Polaris is the last star on the handle of the Little Dipper. (Figure 4-5) Hence, if one could find this constellation, than he would have found Polaris as well.

To identify this constellation, it is important to note that only the two brighter stars, Polaris and Kochab, can be easily seen. Kochab (*Beta Ursae Minoris*) is the star at the forward tip of the dipper, opposite of Polaris.

Observers often find it hard to find the Little Dipper due to its relatively smaller size in comparison with the Big Dipper. If your have the Big Dipper in sight, there is an interesting ancient Greek description that explains the relationship between the 2: "Water pouring from one dipper always falls into the cup of the other dipper."

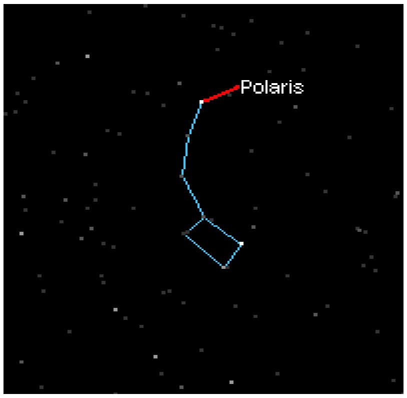


Figure 4-5 *Little Dipper.*

d) Finding Polaris using Auriga

Another constellation that has an easily recognizable shape is Auriga. It has a shape of a pentagon. The pentagon is led by Capella (*Alpha Aurigae*), a star that can be considered to be one of the brightest to be seen in the Northern Hemisphere.

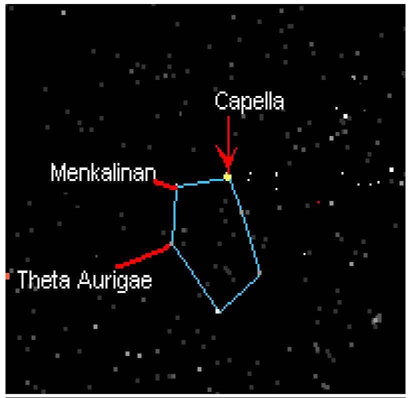


Figure 4-6 *Auriga.*

Instructions:

1. Locate the constellation Auriga and identify the 2 stars nearest to Capella, and directly opposite the longest side of the pentagon. These two stars are called Menkalinan and Theta Aurigae, and are referred to as North Star pointers. Menkalinan is the star closest to Capella.
2. Extend a line from Theta Aurigae to Menkalinan. Note the length of this line.
3. Further extend this line by 5 times its original length from Menkalinan.
4. A fairly bright star found at the end of this line would be Polaris.

e) Finding Polaris using Cygnus, the Northern Cross

For the Northern Hemisphere, there is also a constellation that appears in the shape of a cross, just like the Crux in the Southern Hemisphere. This constellation is named Cygnus.

Unlike its counterpart in the Southern Hemisphere, the Northern Cross is less visible and prominent. Deneb (*Alpha Cygni*), which is at the head of the cross, and Gienah Cygni (*Epsilon Cygni*) are the North Star pointers for this constellation. (Figure 4-7) When the cross is viewed upright, Gienah Cygni appears at the left bottom of Denab.

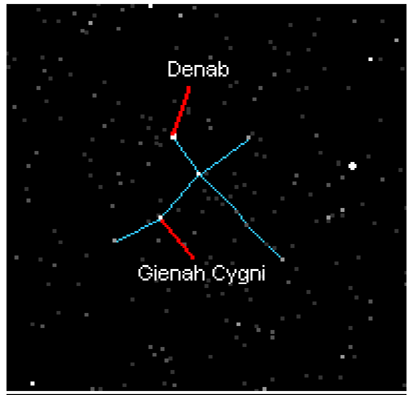


Figure 4-7 *Cygnus*

Instructions:

1. Locate the constellation Cygnus, and identify the 2 North Star pointers, Denab and Gienah Cygni.
2. Extend a line from Gienah Cygni to Denab. Note the distance of this line drawn.
3. Further extend this line by 5 times its original length from Denab.
4. The fairly bright star found at the end of this line is Polaris.

f) Finding Polaris using the Great Square of Pegasus

When viewed, the Great square of Pegasus appears to stretch very broadly across the night sky. As such, this majestic view can be seen in most parts of the Northern Hemisphere quite easily.

The North Star pointers for this constellation are Scheat (*Beta Pegasi*) and Markab (*Alpha Pegasi*). Together, they form a line forming the base of this 'pegasus'. Hence for easy identification, try locating the legs of this creature in order to find the 2 required stars.

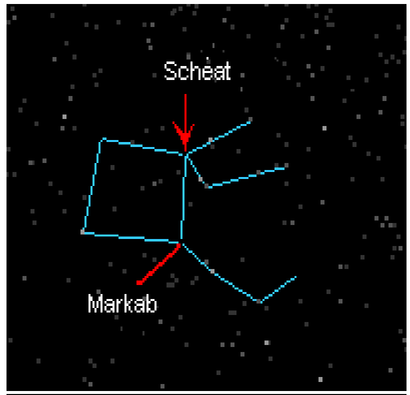


Figure 4-8 *Pegasus*

Instructions:

1. Locate the Great Square of Pegasus and identify the 2 North Star pointers, Markab and Scheat.
2. Extend a line from Markab to Scheat. Note the distance of this line drawn.
3. Further extend this line by 5 times its original length from Scheat.
4. The fairly bright star found at the end of this line is Polaris.

4.5.2 Identifying South Celestial Pole using the Southern Cross and its Nearby Stars

In the Southern Hemisphere, the North Star cannot be seen. Instead, anyone who needs to navigate at night can always depend on the constellation named Crux (more commonly known as the Southern Cross). Just like the North Star in the Northern Hemisphere, the Southern Cross is the one that is most frequently used to navigate general directions.

The Southern Cross is probably the best known constellation in the Southern Hemisphere as it helps an observer to locate the general direction of south and any other direction required. It is highest in the evening sky from March to September.

This group of four bright stars is shaped like a cross that is tilted to one side. The two stars forming the long axis, or stem, of the cross are called pointers. The bright stars of the near constellation of Centaurus are found beside it: Rigil Kentaurus (*Alpha Centauri*) and Hadar (*Beta Centauri*). These two stars as well as a third separate bright star, Achernar (*Alpha Eridani*), help to locate south from the Southern Cross.

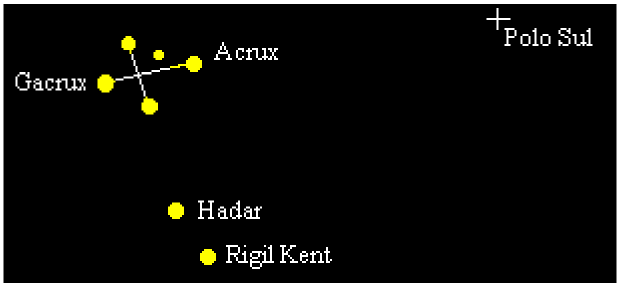


Figure 4-9 *The Southern Cross, Alpha and Beta Centauri*

a) Locating SCP based on the tilt of the Southern Cross

When the Southern Cross appears to be standing straight up, its long axis conveniently points to the SCP.

But when it appears to be tilted at an angle, there are some steps to do in order to locate the SCP.

Instructions:

1. Locate the Southern Cross and identify the 2 stars forming the long axis of the cross. Gacrux (*Gamma Crucis*) is the bright star at the top of the long axis, while Acrux (*Alpha Crucis*) is the bright star directly opposite it. These 2 stars are the South Pole pointers.
2. Extend a line from Acrux which is of approximately 4.5 times the length of the long axis.

3. Extend a second line vertically down from the first line obtained above to obtain an accurate location of the *South Celestial Pole*. (Figure 4-10)

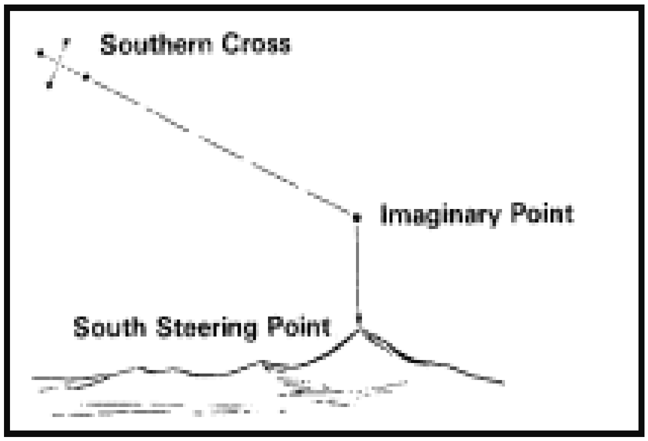


Figure 4-10 *Determining South Celestial Pole using Southern Cross*

b) Using Hadar and Achernar to locate SCP

Instructions:

1. Locate the star, Hadar (closest to the Southern Cross among the 2 bright stars of constellation Centaurus.) It would be useful to know that Rigil Kentaurus and Hadar form an alignment with Gacrux
2. Locate the star, Archernar. (first bright star found by extending the foot of the Southern Cross)
3. *South Celestial Pole* is located as an imaginary vertical line, perpendicular to the horizon, which is drawn halfway between Hadar and Achernar.

c) Using Hadar and Rigil Kentaurus to locate SCP

Instructions:

1. Ensure that the two stars, Hadar and Rigil Kentaurus are visible.
2. Extend a line through the 2 stars.
3. Extend a second line of about 10 finger widths (assuming that the distance between the 2 stars is 2 finger widths), perpendicular to the first line that is through the 2 stars. This line would locate the *South Celestial Pole*.

4.5.3 Observing the apparent motion of stars

The accuracy of direction telling using stars is dependent on a person's position on earth. The degree of error may also increase if a star is picked that is low in the sky. For example, if the star moves horizontally from right to left it indicates the observer is facing North, however, if the observer is in the Southern Hemisphere, and the star is low in the sky, it could mean that the person is facing South instead. (i.e. the star is below the *South Celestial Pole*). To avoid this error, it is advisable to always pick a star high in the sky (greater than your latitude above the horizon).

a) Using stars overhead

At least one or two bright stars can normally be seen in the night sky, no matter where a person is. Bright stars that are very high up or overhead, give a fairly accurate indication of East and West. This is because the motion of overhead stars from an observer on any part of earth is always due West.

This method of finding stars comes in very handy when there are no constellations familiar to you. Hence, by observing the motion of any overhead star, a navigator can find his direction easily.

The best way to observe the apparent motion of the stars is to use a fixed sight, and keep the eye very still. The best way to keep the eye still is to lie down on the back in a comfortable position, with the head comfortably supported. The sight could be a stiff stick supported rigidly so one end is overhead, or a protrusion of rock from an overhead cliff. Trees and branches make poor sights as they move and sway in the slightest breeze. Below is a general method to find the sense of direction.

Materials: A straight stick and string., both of about half a metre long

Instructions:

1. First, selected a bright star.
2. Push the stick at a slight angle into the soft ground.
3. Tie a string (or any line that can be found) to the tip of the stick. Ensure that this string is able to reach the ground with ample remainder. Position in such a way that it is possible for the person observing to pull the cord tautly and hold it next to his temple. (Figure 4-11)
4. After that, adjust the body until the line points directly at the selected bright star. At this point, the string represents the bright star's shadow. A rock is placed at the point where it touches the ground.
5. The process is repeated 2 more times, of thirty minutes interval.
6. Basically, this is just a night version of the ‘stick and shadow’ method to locate general direction. Hence, the first marking made was pointing in the West direction (since the star ‘casted’ a shadow from

the East), while the second mark was pointing in the East direction. A perpendicular line drawn between these 2 lines would enable North and South direction to be found.

Figure 4-11

b) Observing Stars near the horizon

When it is impractical to sight a star directly overhead, the following method may be suitable. This method has limited accuracy and thus only acts as a general guide.

Observe the motions of stars near the horizon of approximately 90 degrees apart:

- Where the stars either move very slowly, or move parallel to the horizon may be either North or South.
- Where the stars rise steeply from the horizon is obviously east, and where they set steeply is West.

4.6 Finding latitude using stars

4.6.1 Rising and setting angle of stars

A person's latitude can be roughly determined by observing either the rising or setting angle of stars with respect to the horizon. This is due to the simple fact that in different parts of the world, due to the tilt of the earth, the apparent rising and setting of celestial bodies such as the sun and stars are different. In other words,

Observer's latitude = 90°– rising/setting angle of star

For example, at 35 degrees South (or North), a star at the east will rise at an angle of 55 degrees from the horizon. This angle will always "lean" towards the equator. This is not a very accurate method (due to observational errors), and will only provide "sense of direction" information. The numerical value of an observer's latitude would decrease as latitude increases. In fact, at the poles, the stars on the horizon simply follow the horizon.

It is extremely difficult to obtain an accurate value of the rising/setting angle of a star without any proper equipment. Hence, try to note the changing positions of the star by putting a fairly straight stick into the ground and aligning it with the star. Estimate the angle that the stick makes, with respect to the horizon.

This method of finding latitude works in most parts on earth (except the poles), and the effective time to carry out the observation is between 2 to 3 hours past the rising time of the star. (or 2 to 3 hours before the setting time)

4.6.2 Altitude of North Star

In the Northern Hemisphere, Polaris can also be used to find a person's latitude. When a navigator faces North, the altitude of Polaris with respect to the horizon is our latitude. In other words,

Observers latitude = Altitude of the North Star

Hence, as a person travels further away from North, the altitude of Polaris decreases, together with his latitude.

Improvised Navigation: Observing Natural Features

Navigation by observing natural features is one of the simplest ways of finding your way around. Although this improvised way navigation isn't very accurate, it is one that does not require any special skill or instrument. Natural features such as rivers, trees and snow can provide us with clues to find our way out of the wilderness.

Unlike navigation with celestial bodies, such methods are not meant to be precise. It merely allows a person to get to know his 'general direction'. In fact, many people complement these methods with their routine use of tools and maps to greater effectiveness. This chapter would attempt to highlight this interesting way of navigation by focusing on the more commonly seen and known thing around us.

5.1 Terrains

5.1.1 Melting Snow

Earth is always rotating and revolving around the Sun at a tilted axis. Therefore the Sun's apparent position is always changing day by day.

Since the ecliptic is tilted at 23.5 degrees with respect to the celestial equator, the Sun's maximum angular distance from the celestial equator is 23.5 degrees. This happens only during the solstices. For observers in the Northern and Southern Hemisphere, the furthest northern point that the sun can move to on the ecliptic is at the summer solstice, and the furthest southern point is at the winter solstices. Thus, at the Northern Hemisphere during summer solstice (when the sun is at its maximum height), the sun does not rise high up above the horizon and its rays hit the ground at an angle in the south. Whereas, at the Southern Hemisphere during winter solstice (when the sun is at its maximum height), the Sun's ray hit the ground at an angle in the North.

From this, we can observe that in the Northern Hemisphere, the slopes facing North would receive less sunlight than those facing South. In the Southern hemisphere, an opposite effect takes place.

This causes the north-facing slopes in the Northern hemisphere and the south-facing slopes in the Southern hemisphere to be cooler and damper. Knowing this, an observer would be able to make some observation that would enable him to locate the direction of North and South. The observations are:

- At the inter-phase of winter and summer, snow on the slopes facing South will start to melt first and at a higher rate. This causes the ground snow to be relatively shallower than those slopes facing North.
- In summer, after most of the exposing snow has melted, the slopes facing North will still retain traces of snow at some hidden, sheltered and concave part of the slope
- For both observations listed above, the opposite is true for the snow on the slopes found in the Southern Hemisphere.

Such observations would be more useful on relatively high and rocky mountains. This is because the height of these mountains would further contrast the effects of uneven distribution of sunlight on the North and South facing slopes.

These observations are limited by the fact that they are only clearly visible during summer or during the inter-phases of winter and summer.

5.1.2 Ant Holes

Other than the above methods, we can also make use of ant holes. Ants usually built their nest such that its hole is positioned away from direct sunlight. This is to facilitate control of internal temperature within the nest itself.

By observing where an ant hole is facing, you can deduce the general direction. In the same direction with the ant hole, one will face the North if he's in the Northern Hemisphere and he will face the South if he's in the Southern Hemisphere. The concept behind is similar to the one mentioned in 5.1.1.

5.2 Vegetations

5.2.1 Plants

a) Lichens

Lichens are species of plants that grow well in shady and moist surfaces. It can be found anywhere, including residential backyards. A well-known example of such species is Mosses (Figure 5-1). Mosses thrive easily in such damp conditions and can be found mostly on tree trunks.

Figure 5-1 *Mosses*

The concept behind the observations is once again similar to that mentioned in 5.1.1.At higher latitudes in the Northern Hemisphere, mosses grow more densely and greener on the South-facing side of the tree as compared to the North-facing side. The opposite is true for the Southern Hemisphere.

Other different species of Mosses are shown in Figure 5-2 and 5-3

Figure 5-2 *Scapania*

Figure 5-3 *Asterella*

b) Indicator Plants

There are some special plants which will grow in a particular direction. And spotting them when you are lost can be very useful for finding your way.

Compass Plant

The type of plant shown in Figure 5-4 is commonly found in North America. The direction of its leaves is normally aligned in a North-South manner. Its strange growth profile allows an observer to make a rough estimation of North and South direction. This would be more accurate if all the plants in the vicinity are positioned in the same manner.

The plant is named in this way because of the fact that the direction pointing leaves resemble the needles of a compass.

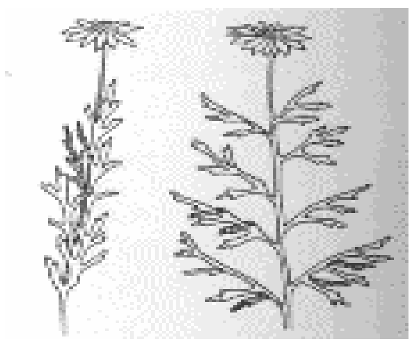


Figure 5-4 *Compass plant*

North Pole Plant

The plant shown on Figure 5-5 grows in South Africa, and it leans towards the north to gain full advantage of the sun. Spotting this particular plant can help find North direction.

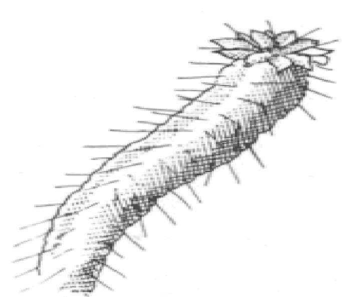


Figure 5-5 *North pole plant*

5.2.2 Trees

Trees are useful as they provide several directional signs. Some of the methods of finding direction from the trees would be discussed below.

Branches and Leaves

In the Northern Hemisphere, trees will have more branches and leaves at the South facing side. (Figure 5-6) This is because trees will try to grow towards the Sun. As a result, the South-facing side of the trees will be denser and more bushy than the North-facing side. This is especially true for Connifers such as the Willow, Polars and Alders.

The opposite is true in the Southern Hemisphere.

Figure 5-6

Bark of the tree

Trees found in the Northern Hemisphere such as the Birch shown in Figure 5-7 below and other Poplar trees have bark which is whiter on the North side and darker on the South. This is similar to sun tanning effect, where the surface that is exposed to longer direct sunlight will turn darker.

Figure 5-7 *Birch*

As for the Southern Hemisphere, the bark will be whiter at the South side and darker in the North side.

Growth Rings on Stumps

This method is more applicable if you are able to chop a tree or you are in an area with a lot of felled trees. Take a close look at the cross-section of the trees and observe the growth rings. Normally, these growth rings (shown in Figure 5-8) would not be evenly spaced.

Figure 5-8 *Growth rings*

In the Southern Hemisphere, growth rings of trees would generally be closely spaced at the side facing the South, while the North-facing side will have widely spaced growth rings. The different rate of growth for the two sides is due to the different amount of sunlight that each side received. As for the Northern Hemisphere, it is simply the opposite.

Fruits

Another way of getting direction from the trees is by observing the fruits hanging from the branches. In general, the side facing the Equator will have fruits ripen at a faster rate, and it will also produce more fruits.

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