UNIT 3 COMPASS SURVEYING

Structure

3.1 INTRODUCTION

In Units l and 2, you have learnt that the general objective of surveying is to determine the relative positions of distinctive features on ground (in the area under study) in order to prepare maps which can be used in future for various engineering applications, e.g. planning, designing and executing civil engineering projects. This, in general, will consist of measuring distances, both horizontal and vertical, and angles. In Unit 2, you have studied different methods of measuring horizontal distance along the survey lines and offset distances of ground features from survey lines.

However, if the area to be surveyed is comparatively large it is rather difficult and inaccurate to obtain all the required distances by measuring horizontal distances only. In real life situations, there are many obstructions and difficulties in direct ranging the survey lines. It becomes very tedious and inconvenient, even impossible, to fix the directions of survey lines by linear horizontal measurements alone. These problems can be conveniently solved by making angular measurements. The directions of survey lines can be easily fixed by measuring the angles between two survey lines meeting at a station or angle of a line with reference to some fixed axis. The direction of a line relative to a given fixed axis (or meridian) is called its bearing. Traversing becomes quite convenient by carrying out the measurements along a series of interconnected survey lines either to form a closed or an open traverse. The lengths and offsets are measured by chain or tape while directions of survey lines are measured using compass or any angle measuring instrument. This process is termed as chain and compass survey.

Objectives

After studying this unit, you should be able to

- understand various important terms and instruments used in compass surveying,
- understand the procedure of compass surveying,
- measure bearing of survey lines and find the angle between these lines, and
- know various types of error involved in compass surveying, their source and methods of correction.

3.2 DEFINITIONS AND IMPORTANT TERMS

The instruments commonly used for angular measurements are the compass and theodolite. Before the study of instrument and procedures used for compass surveying, it is necessary to define some important terms commonly used in this context.

3.2.1 Bearing

The horizontal angle between the reference meridian and the survey line is termed as bearing of the survey line.

Magnetic Bearing

The magnetic needle of the compass always points towards the magnetic north-south (N-S) direction indicating earth's magnetic axis. Since this direction is same at all the places on the earth's surface, it is universally used as the reference direction. The angle made by survey line in a clockwise direction with reference to magnetic N-S line is termed as magnetic bearing of the line. The value of magnetic bearing ranges from 0^o to 360^o.

True Bearing

The geographical north of earth is different from the magnetic north. Hence, the angle which the survey line makes with the true geographical north is termed as true bearing of the survey line.

Arbitrary Bearing

It is the horizontal angle which a survey line makes with any arbitrary meridian, which is any convenient direction towards a permanent and prominent mark or signal, such as a church spire or top of a chimney. Such bearings are used to determine the relative position of line in a small area.

Whole Circle Bearing (WCB)

The complete circle of angular measurement starts with north as 0^o and ends at north at 360^o. The bearing of line directly obtained by magnetic needle ranging from 0^o to 360^o is called whole circle bearing as shown in Figure 3.1(a).

Reduced Bearing (RB)

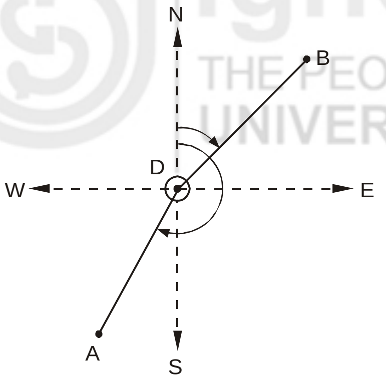
The more convenient way to comprehend the direction of a survey line is to represent the bearing on a quadrantal system. The angle is measured with respect to N–S line towards east or west as shown in Figure 3.1(b). The relationship between WCB and RB is shown in Figure 3.1(c).

Fore Bearing (FB)

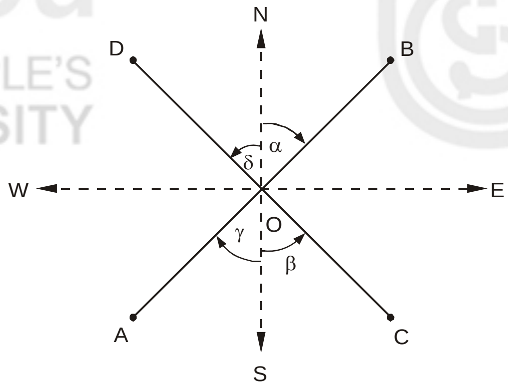
The angle measured in the direction of survey line from starting survey station to the next station is called fore bearing. In Figure 3.1(d), if the bearing of line AB is measured from A towards B, it is known as forward bearing or fore bearing.

Back Bearing (BB)

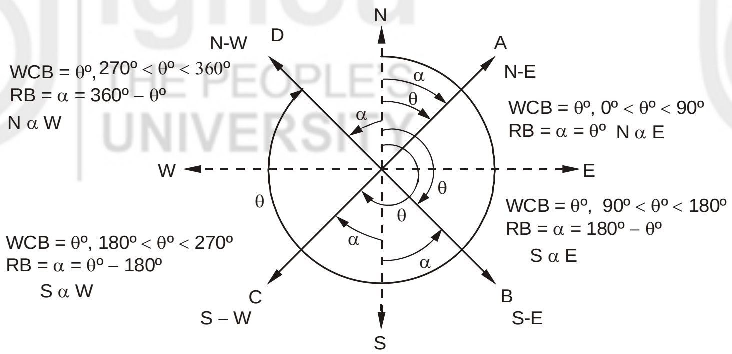
It is the bearing of the survey line taken from the forward survey station to the preceding station from which the fore bearing was taken earlier. In Figure 3.1(d), if the bearing of same line AB is measured from B towards A, it is known as backward bearing or back bearing.



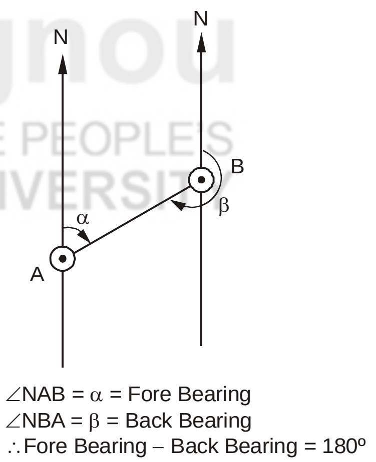
(a) Whole Circle Bearing



(b) Reduced Bearing



(c) Relationship between WCB and RB



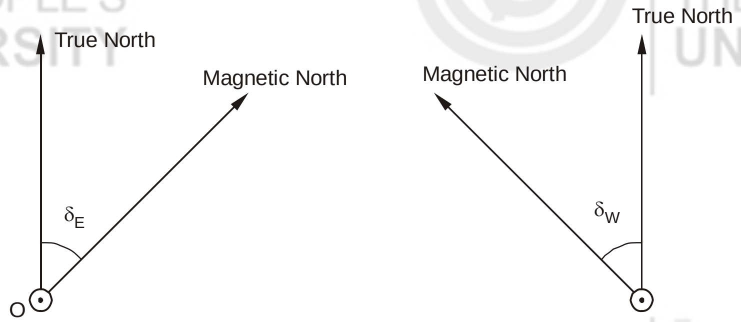
(d) Fore Bearing and Back Bearing

Figure 3.1 : Bearing of a Survey Line

3.2.2 Magnetic Declination

The direction of magnetic meridian varies from place to place across the globe. Hence, the bearings taken with reference to magnetic meridian of the survey lines will not represent true relative angles between them. The errors can be negligible for smaller area surveys but will be quite significant for large surveys particularly geodetic and astronomical surveys. A more accurate method of denoting the bearing of a survey line will be to obtain the true bearing of the line. The difference between true bearing and magnetic bearing of a survey line at a survey station is called magnetic declination of that place.

Hence, the horizontal angle made by magnetic meridian and true meridian at a place is termed as magnetic declination of that place as depicted in Figure 3.2. The magnetic declination could be East declination Figure 3.2(a) or West declination as in Figure 3.2(b) indicating whether magnetic North is toward East or towards West of true North.



(a) East Declination δ_E **(b) West Declination δ_W**

Figure 3.2 : Magnetic Declination

It may also be noted here that position of magnetic North may change even at a station due to several factors. Hence, it may be necessary to record the date of survey and time to obtain the true bearing of a survey line at a place. Astronomical observations are required to be taken to determine the direction of true North at a place and hence to obtain the true bearing of a survey line at that place. Magnetic bearing can be easily obtained for the same line by compass survey. The difference between true bearing and magnetic bearing of the survey line so obtained will give the magnetic declination at that place, i.e.

Magnetic Declination = (True Bearing – Magnetic Bearing)

The magnetic declination will be positive if magnetic meridian is towards east of true meridian and negative if magnetic meridian is westward of true meridian.

Isogonic Lines

If the points on the globe which have same magnetic declination at a point of time are joined, the imaginary lines so obtained are called isogonic lines.

Agonic Lines

These are imaginary lines constructed by joining the points at which the magnetic declination is zero, and hence have the same value of magnetic bearing and true bearings.

For reference to geodetic and other important surveys, isogonic charts are published by agencies like Survey of India, on which isogonic and agonic lines are drawn on earth maps.

3.2.3 Magnetic Dip

The magnetic bearing of a survey line at a place is obtained by using a magnetic compass. The needle of this compass will not remain horizontal due to magnetic influence of the earth. This deflection of the needle from the horizontal position is called dip of the needle. Apart from local effects due to presence of magnetic ores in ground or such other localised influences, the magnetic dip of the compass needle will vary from place to place on the surface of earth. It will be horizontal at equator, i.e. zero dip at a place equidistant from both the poles. The deviation from horizontal position will gradually increase as survey lines moves toward the poles. This dip will influence the accurate recording of the bearings. A sliding weight or an aluminium coil can be placed on the higher side of the needle to counter balance this dip and make the needle perfectly horizontal during bearing measurements.

SAQ 1

(a) Define the terms True and Magnetic bearing, Fore and Back bearing, Magnetic dip and Magnetic declination.

(b) In an old survey, the value of magnetic declination was 4^{o}W at the time it was made and the magnetic bearing of a given line was 210^{o}. The declination in the same locality is 10^{o}E now. What are true and present magnetic bearing of the line.

3.3 INSTRUMENTS AND PROCEDURES

3.3.1 Compass

The compass essentially consists of a freely suspended magnetic needle mounted on a smooth pointed pivot. The needle can freely move over a graduated scale. Two slit vanes are provided on the frame – one as the object vane and other as eye vane – placed at 180^{o} to provide the line of sight. A tripod stand is provided on which the compass can be mounted and positioned over the survey station, while taking observations.

A circular metal box, approximately 100 mm diameter, is used with a hardened steel pivot at the centre. The magnetic needle, graduated aluminium ring and vanes etc. are other parts of the compass. Design of these parts and their placement vary in different types of compass.

The two types of compass – prismatic compass and surveyors compass – are currently used in practice.

Prismatic Compass

It is the commonly used compass for engineering surveys and is suitable for surveys where speed is more important than accuracy, for example, the preliminary surveys of road, railway line or pipe line alignments and rough traversing etc. Figure 3.3 shows the different constituents of a prismatic compass in their final assembled form.

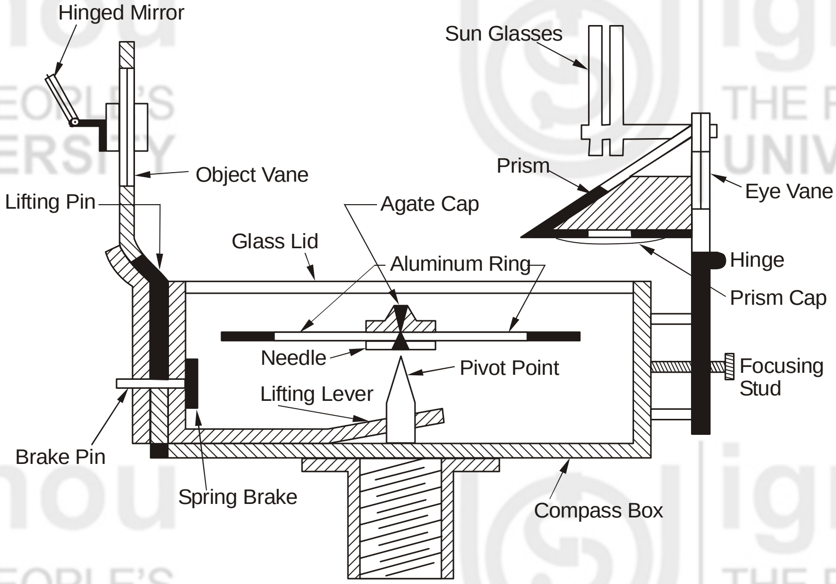
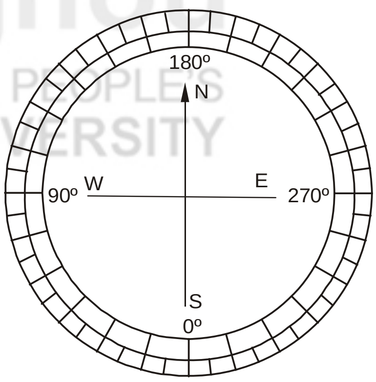


Figure 3.3 : Prismatic Compass

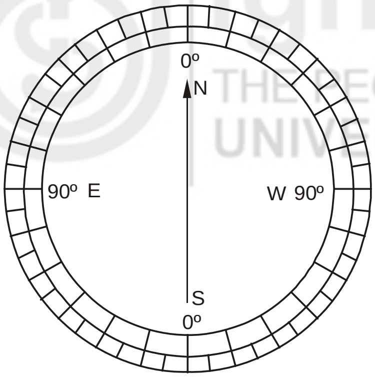
The aluminium ring of prismatic compass has a magnetic needle marked with N-S along the diameter of the ring. The graduations are itched from 0^o to 360^o in clockwise direction with zero marked at south end of needle and 180^o at the north end (Figure 3.4(a)). The itching is marked in inverted fashion so that they are read in correct way when viewed through the reflecting prism. Each degree in graduation is divided into half to give a least count of 30'.

The object vane has a vertical hair thin wire bisecting the object under observation. The observation vane (or eye vane) consists of a reflecting prism. Both the vanes are collapsible to be folded to lie on compass cover when not in use. A plane mirror is hinged to object vane to sight the object which is too high or too low to be sighted directly. The indication of mirror can be adjusted to facilitate this process. In case of sun glare, when making the measurements become difficult, sun screen of tinted glasses can be used by placing them in the line of sight between prism and object vane.

To dampen the oscillation of magnetic needle and providing stability to measurement process, a brake pin is provided on the side of the compass box. A lifting pin is also provided to lift the needle and to keep it pressed against glass cover when the object vane is folded and the compass is not in use. This prevents the pivot from excessive wear and tear.



(a) Prismatic Compass



(b) Surveyor's Compass

Figure 3.4 : System of Graduation

Surveyor Compass

This instrument is more or less obsolete these days and not often used for land surveying. Its construction is somewhat similar to prismatic compass except that it has plane sight vane with a narrow vertical slit in place in prism. The graduations on scale vary from 0^o to 90^o with 0^o at North and South and 90^o at East and West positions marked (Figure 3.4(b)). The magnetic needle is edge bar type while the circular graduated scale is fixed with the box. Thus, here, instead of whole circle bearing, reduced bearings are recorded.

3.3.2 Procedure of Measuring Bearing with Prismatic Compass

The procedure of measuring bearing with the compass is discussed in this section along with some related issues like compass traversing, local attraction and correction due to local attraction.

Setting the Compass at Station

The prismatic compass is required to be temporarily set over the station at which the bearing of survey line required to be measured. It is basically a two-step procedure. This is also called the temporary adjustments of compass.

Centering

The compass is set so that its centre lies exactly above the station under consideration. This is achieved by suspending a plumb bob from the centre hook provided. If the conical end of plumb bob lie exactly over the station (*X* is marked over station for accuracy), the compass is considered to be exactly centered. If not, the legs of the tripod are adjusted in position by moving one leg first and then simultaneously moving other two legs in perpendicular direction to first movement. Several trials can be needed for obtaining the correct centering of the compass. In real life situations, when plumb bob is not available, a small piece of stone or pebble can be taken, by holding this stone by fingers in line of centre of compass and allowing it to drop freely on the station. If the stone falls on the top of peg then centering is correct, otherwise the adjustment of tripod is done as explained earlier.

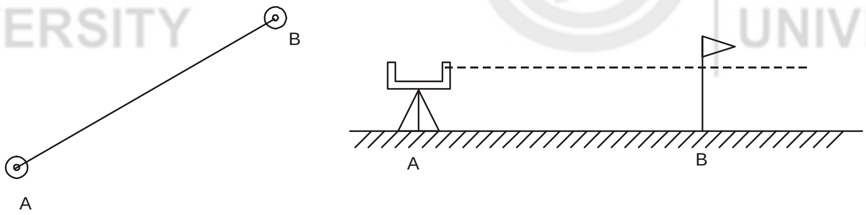
Levelling

The compass is required to be levelled so that the aluminium ring is in horizontal plane and hence free to rotate on pivot. The levelling can be checked by a spirit level or by rolling a pin on compass box. If the round pin does not roll, the level is correct. If not levelled correctly, the level can be adjusted by moving the legs of tripod. Some instruments are provided with a ball and socket arrangement at box base to achieve rapid levelling till the graduated ring moves freely inside the compass box.

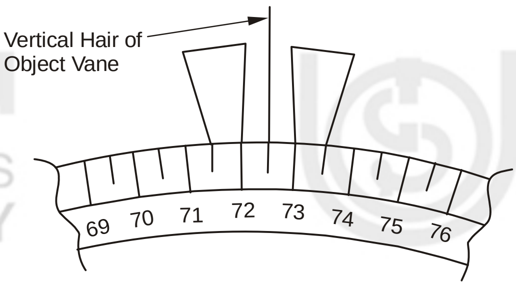
Observing the Bearing

Once the compass is centered over the station and levelled, the process of bearing measurement can start. Let *AB* be the survey line as shown in Figure 3.5(a), the bearing of which is required to be measured. The instrument is set at *A* and a ranging rod is fixed at *B*.

The compass is turned so that line of sight is aligned in the direction of *AB* by making eye slit of observation vane, vertical hair of object vane and ranging rod at *B* in same horizontal line. Wait for oscillation of graduation ring to dampen, with the use of brake pin if necessary. The viewing prism is focused by moving it vertically with the help of focusing stud. The reading of the image of hair line as observed through prism is noted indicating the whole circle bearing of survey line. The process is repeated to check the repeatability of measurements. This bearing is called fore bearing of line *AB*.



(a) Survey Line AB **(b) Compass Set at A**



(c) Reading on Compass

Figure 3.5 : Recording of Bearing

Traversing

The instrument is successively set at each station of the traverse and the fore bearing and back bearing of each line is taken and recorded in the field notebook. The observational errors in this survey tend to compensate as each bearing is observed independently. Distances between each survey stations are measured using a chain/tape. The offset points are located either by procedure followed in chain surveying or by angular measurement with compass.

The bearings of survey lines in a traverse are observed in progressive way. The bearing recorded in the direction of progress of survey is called the fore bearing while the bearing of the same survey line from the end station (station *B* on line *AB*) is termed back bearing (Figure 3.1(d)).

It can be noted that *back bearing of a line is equal to its fore bearing* $\pm 180^o$. Plus sign is used when fore bearing is less than 180^o and minus sign is used when it is more than 180^o.

Local Attraction

The bearings measured by prismatic compass are magnetic bearings measured with reference to magnetic north of the earth. Apart from the fact that magnetic meridian changes from place to place on earth and with time of observation, external magnetic influence existing locally at a place can influence the readings seriously. The local presence of magnetic rocks, iron ore deposits, steel structures, railway lines, iron electric poles etc. can seriously deflect the magnetic needle of compass from its normal positions. Such disturbances in accuracy of measurements are termed local attraction. The actual measurements of bearings can also be disturbed if the surveyors, carelessly keeps bunch of iron keys, iron knives or buttons, steel framed spectacles. Even the chains and arrows, used in surveying, near the compass can also affect bearings. Proximity of such objects should be avoided as far as possible during compass surveying.

The existence of local attraction can be detected by recording the fore bearing and back bearing of the survey line from both end stations. Any difference between back bearing and fore bearing other than 180^o will indicate the presence of local attraction if no instrumental and observational error is involved in the measurement process.

Adjustments and Corrections

It may be noted that the presence of local attraction will affect all the bearings taken at a particular station in the same way. Hence, the difference between the bearings of lines recorded at a particular station, giving the included angle between the survey lines will have the correct value even when the station is observed to have the local attraction disturbances.

The corrections in the recorded bearings at a station influenced by local attraction can be made by either of the following methods.

(a) The difference between fore bearings and back bearings of all the survey lines are determined. The line having a difference of exactly 180^o is selected as unaffected line. The magnitude and direction of error, i.e. the deviation from 180^o and its sign (+ ve if more than 180^o and – ve if less than 180^o) at other stations is determined. The corrections are thus applied to other survey lines with reference to unaffected line.

(b) Included angles of all the survey lines are computed for closed traverses. The sum of these included angles shall be equal to $(2n - 4)$ right angles, where n is number of survey lines in the traverse. The error if any in the sum of included angles is then distributed either equally or in proportion to the magnitude of angle, to all the angles once again starting from the unaffected line. The bearings of other lines are corrected by taking the corrected values of included angles.

(c) If no line can be located which has a 180^o difference between its fore and back bearing, the survey line with minimum deviation is selected and the error is equally applied in fore bearing and back bearing to bring the difference to exactly 180^o. The bearing of other lines are then corrected following the procedure discussed above.

SAQ 2

(a) Describe the procedure of measuring magnetic bearing of a survey line.

(b) What is local attraction? How is it detected and eliminated?

3.4 CALCULATIONS OF BEARING AND INCLUDED ANGLES

3.4.1 Calculation of Included Angles

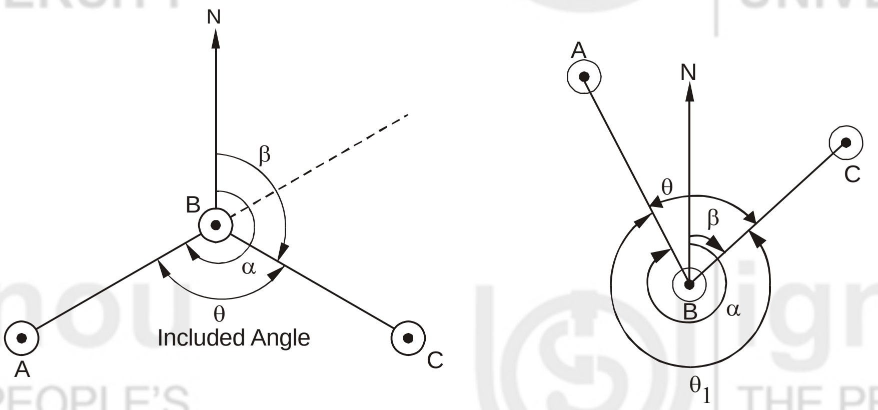
Having conducted the compass survey as described in Section 3.3, next step in plotting the survey results on maps is to calculate the included angle between two consecutive survey lines of the traverse.

(a) If the whole circle bearings of two lines at a station where these lines intersect are recorded, then the included angle between these lines would be equal to the difference between the whole circle bearings of two lines. If the difference is less than 180° the included angle would be interior angle and if it is more that 180° it will be the exterior angle between the two lines forming the traverse (Figure 3.6).

In Figure 3.6(a), it is given that back bearing (*BB*) of line *AB*, i.e. (α) = 240° and fore bearing (*FB*) of line *BC*, (β) = 120°. Then the included angle *ABC*, $\theta = \alpha - \beta = 240^o - 120^o = 120^o$. Therefore, it can be said that if both the bearings are measured from a common point (*B*) then included angle can be obtained by subtracting *FB* of next line (*BC*) from the *BB* of previous line (*AB*).

In Figure 3.6(b), if α is given as 330° and β as 40° then $\theta_1 = 330^o - 40^o = 290^o$ is the exterior angle. In this case, included angle θ would be 360° – (difference between *WCB* of lines *BA* and *BC*).

Hence, included angle $\theta = 360^o - \theta_1 = 360^o - 290^o = 70^o$.



(a) **(b)**

Figure 3.6 : Included Angle from *WCB*

(b) If the *WCB* at point of intersection of survey lines *AB* and *BC* (i.e. at station *B*) are not given but rather fore bearing of line *AB* (i.e. *WCB* of line *AB* at *A*) and back bearing of line *BC* (i.e. *WCB* of line *BC* at *C*) are known, then the included angle at station *B* between survey lines *AB* and *BC* (Figure 3.7) can be obtained as follows.

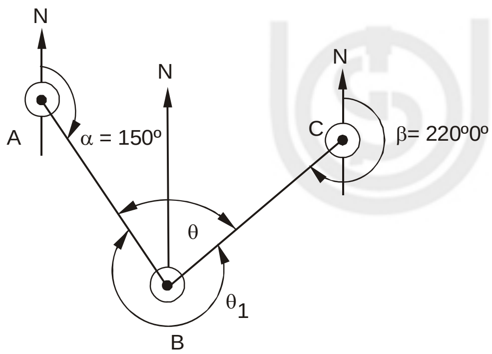


Figure 3.7

WCB of *AB* at *B* = Back bearing of line *AB* at *B* = 150° + 180° = 330°.

Back bearing of line *BC* at *C* = 220°.

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WCB of *BC* at *B* = Fore bearing of line *BC* at *B* = $220^o - 180^o = 40^o$.

Included angle $\theta_1 = 340^o - 40^o = 290^o$ = Exterior angle.

Hence, Interior angle $\theta = 360^o - \theta_1 = 360^o - 290^o = 70^o$.

3.4.2 Calculation of Bearing from Angles

If included angles measured clockwise between survey lines at stations and bearing of any one line are known, bearings of all other lines can be calculated as follows :

Bearing of a line = Given bearing of adjacent line + Included angle (measured clockwise) between the lines.

If the sum is more than 360^o, then deduct 360^o to obtain the bearing of the line.

The process is explained with the help of following examples.

(a) Let fore bearing of line *AB*, α and included angle θ between *AB* and *BC* are given.

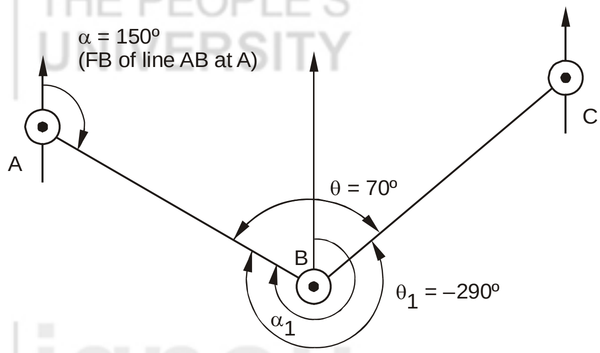


Figure 3.8 : Bearing from Included Angle

Then back bearing of line *AB* at *B* would be

$$\alpha_1 = 150^o + 180^o = 330^o$$

Included angle $\theta = 70^o$

Then fore bearing of line *BC* = $330^o + 70^o = 400^o > 360^o$.

$\therefore$ Fore bearing of line *BC* = $400^o - 360^o = 40^o$.

(b) Let fore bearing of line *BC* and included angle θ is given. Included angle θ measured from *BC* to *BA* = 70^o measured counterclockwise or will be $360^o - 70^o = 290^o$ measured clockwise. Hence the back bearing of line *AB*, i.e. *WCB* of line *AB* at *B* would be $40^o + 290^o = 330^o$ measured clock wise.

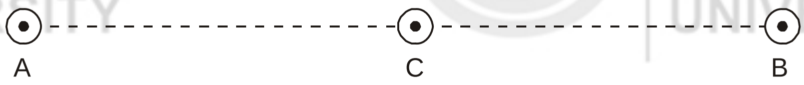
3.5 PRECAUTIONS AND ERRORS IN COMPASS SURVEY

3.5.1 Precautions

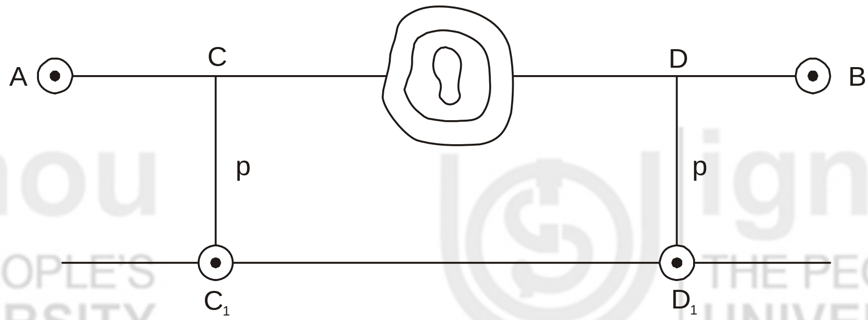
While undertaking the compass traversing, following precautions should normally be observed.

Bearing

If it is difficult to observe the location of the ranging rod at station *B* from compass set at station *A* for obtaining the bearing of survey line *AB*, locate an intermediate station *C* on line *AB*, which can be sighted from both stations *A* and *B*. The compass can then be set over the intermediate station *C*. When there is an optical obstruction in the line *AB*, a parallel line $C_1 D_1$ is set out by means of offsets as nearly as possible (Figure 3.9(b)) and get the bearing of the survey line.



(a)



(b) Line Parallel to Survey Line AB

Figure 3.9 : Bearings when Two Stations are not Intervisible

Freeing the Needle

The magnetic needle has to rotate freely over the pivot to get accurate measurement of bearing of the survey line. Tap the compass box after the needle has come to rest. This helps in overcoming the pivot friction, if any. The cover glass may also have gathered static electric charge, when rubbed with cloth while dusting and thus attract and jam the magnetic needle of compass. The glass has to be discharged by applying moist finger on its surface.

Damping

The vibration of compass needle are damped by gently pressing the braking knob. To reduce vibrations and to minimize wear and tear of pivot point, the needle shall be released only when the compass is aligned approximately in the direction of magnetic meridian at site.

It is always advisable to take duplicate reading of the needle for each bearing measurements. After noting down the first reading the compass is rotated to displace the needle. Readjust the needle before taking the duplicate reading. This reduces observational errors.

3.5.2 Sources of Error

Various errors observed during a compass survey can be broadly classified as Instrumental errors, Observational errors and External influences.

Instrumental Errors

These could be due to defective manufacture or due to damage to instrument during rough handling, transportation and use. For example,

(a) The needle may not be perfectly straight or balanced.

(b) Needle loosing its magnetic property.

(c) The pivot may become blunt or bent.

(d) The plane of sight loosing its verticality and/or twisted so that it is not passing through the centre of compass.

(e) The graduated circle may loose its shape or horizontality.

Observational Errors

Even when the instrument is in perfect order, some errors may occur during bearing measurements. These can be due to

(a) Setting and levelling inaccuracies, i.e. the compass center may not coincide the center point of survey station, or it may not be levelled accurately so that it does not lie in a horizontal plane.

(b) Ranging inaccuracies, i.e. the ranging rods at other object stations may not be fixed in vertical position or these may not be perfectly bisected by line of sight.

(c) Reading and recording inaccuracies, i.e. due to carelessness, the position of line of sight may either be not read properly or accurately or wrongly recorded in field notebook.

External Influences

Perfect instruments and their perfect use may not make the measurements error free because of the following reasons :

(a) Magnetic storms, sunspots, lunar perturbations or minor tremors in earth may cause irregular variations in bearing measurements.

(b) Secular, annual and/or diurnal variations in declination affect the bearing accuracy due to variation in magnetic meridian.

(c) The local attraction due to presence of iron ore in ground, or steel structures, electric lines etc. in the vicinity of survey stations.

3.5.3 Error Prevention

Having observed various types of possible errors during compass surveying, the surveyor has to take adequate measures during actual use of instrument to minimize the effects of these errors. Some of these are given below.

Ensure Horizontality of Needle and Scale

If the needle is not horizontal even when the compass is levelled properly, a small coil of brass rider is used by sliding it on needle towards the higher end of needle. Proper adjustment of rider will make the needle and scale horizontal.

Ensure that Pivot is Central to Scale

Readings at both, North and South, end of needle are recorded. The difference shall be exactly 180^o. Any deviation from this will indicate that either the needle is not straight or the pivot is bent. If the difference between N- and S-readings is constant for different positions of compass, though it may not be 180^o, it will indicate that needle is not straight while pivot is in centre. The needle is carefully observed and straightened to remove this deviation. If the deviation is not same for different compass position, pivot bending is indicated. Pivot is bent and needle straightened to remove this error.

Ensure Verticality of Plane of Sight

A plumb bob is suspended in front of the compass set in position and is observed through the instrument. The eye vane, the object vane and the string of plumb bob shall be in same vertical plane. Any deviation will indicate the loss of verticality of either the eye vane or object vane which are then adjusted accordingly.

Closing Error

When a closed traverse survey is conducted and the results plotted, it may be observed that traverse fails to close. Actual distance by which traverse fail to close is called the closing error. These could be either due to

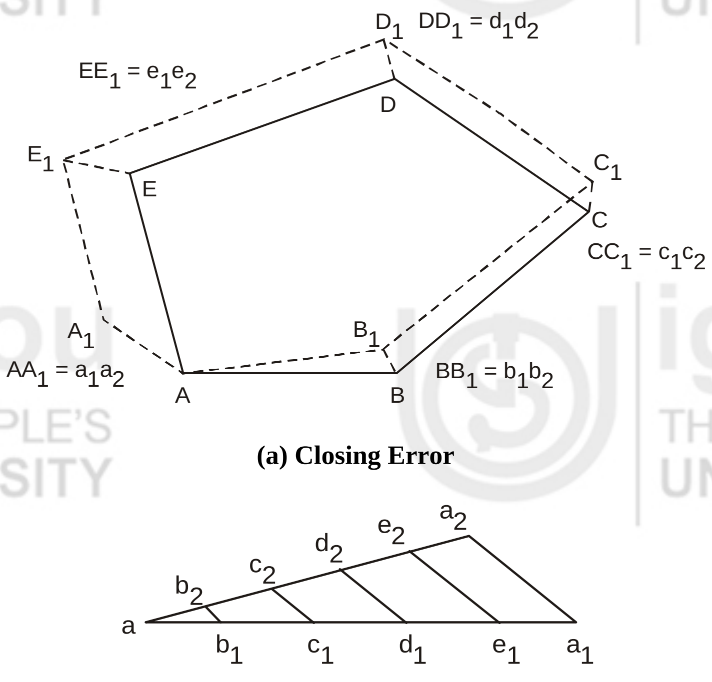
(a) error in measuring angles, or

(b) error in measuring distances.

All the included angles of the traverse are computed from the recorded bearings and aggregated. If the aggregated included angle is equal to $(2n - 4)$ right angles, the angle measurements are correct provided there is no local attraction influence or observational error. Any difference will indicate error in angular measurement. If the closing error is large, the survey is rejected and repeated. If it is small, the error can be corrected by making small adjustments in bearings as explained in Section 3.3.2 under "Adjustments and Corrections".

Errors in Chaining

The traverse may fail to close even when angles are error free. For example the traverse starting from A is plotted as $A\ B_1\ C_1\ D_1\ E_1\ A_1$ in Figure 3.10(a). The end point A_1 does not coincide with A indicating closing error. If error AA_1 is large, the survey has to be repeated. However, if it is small, it can be adjusted as described below.



(a) Closing Error

(b) Error Adjustment

Figure 3.10 : Errors in Chaining

Plot a straight line $a\,b_1\,c_1\,d_1\,e_1\,a_1$ ($ab_1 = AB_1$, $b_1\,c_1 = B_1\,C_1$ and so on) on any suitable scale. At end a_1, draw a line $a_1\,a_2$ parallel to and equal to closing error AA_1 and join $a - a_2$. Draw lines parallel to $a_1\,a_2$ from e_1, d_1, c_1 and b_1 (Figure 3.10(b)) to intersect aa_2 at e_2, d_2, c_2 and b_2 respectively. The distances $b_1\,b_2$, $c_1\,c_2$, $d_1\,d_2$, $e_1\,e_2$ will represent the corresponding corrections by which station B_1, C_1, D_1 and E_1 are required to be shifted as in Figure 3.10(a) for traverse to close. *ABCDE* will then represent the corrected closed traverse.

Example 3.1

Convert the following whole circle bearings to reduced bearings

(a) $42^o\ 58'$

(b) $156^o\ 12'$

(c) $219^o\ 47'$

(d) $327^o\ 34'$

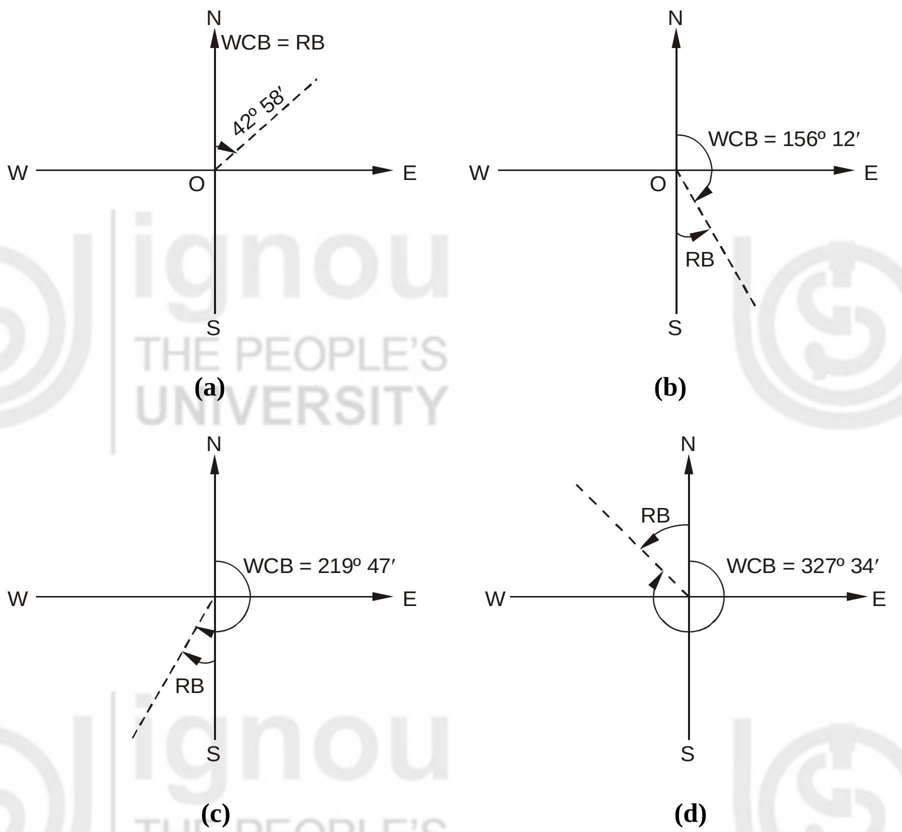


Figure 3.11 : *RB* from *WCB*

Solution

The conversion can be conveniently achieved with the help of sketches as shown below :

(a) *WCB* = $42^o\ 58'$

The survey line lies in 1st quadrant

Hence *RB* = *WCB*, i.e. *RB* = N $42^o\ 58'$ E

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(b) $WCB = 156^o\ 12'$

In second quadrant $RB = 180^o - WCB$

$= 180^o - 156^o\ 12' = S\ 33^o\ 48'\ E$

(c) $WCB = 219^o\ 47'$

In third quadrant

$RB = WCB - 180^o$

$= 219^o\ 47' - 180^o = S\ 39^o\ 47'\ W$

(d) $WCB = 327^o\ 34'$

In fourth quadrant

$RB = 360^o - WCB$

$= 360^o - 327^o 34' = N\ 32^o\ 26'\ W$

Example 3.2

Convert the following reduced bearings to whole circle bearings

(a) N $68^o\ 32'$ E

(b) S $37^o 16'$ E

(c) S $54^o 32'$ W

(d) N $39^o 52'$ W.

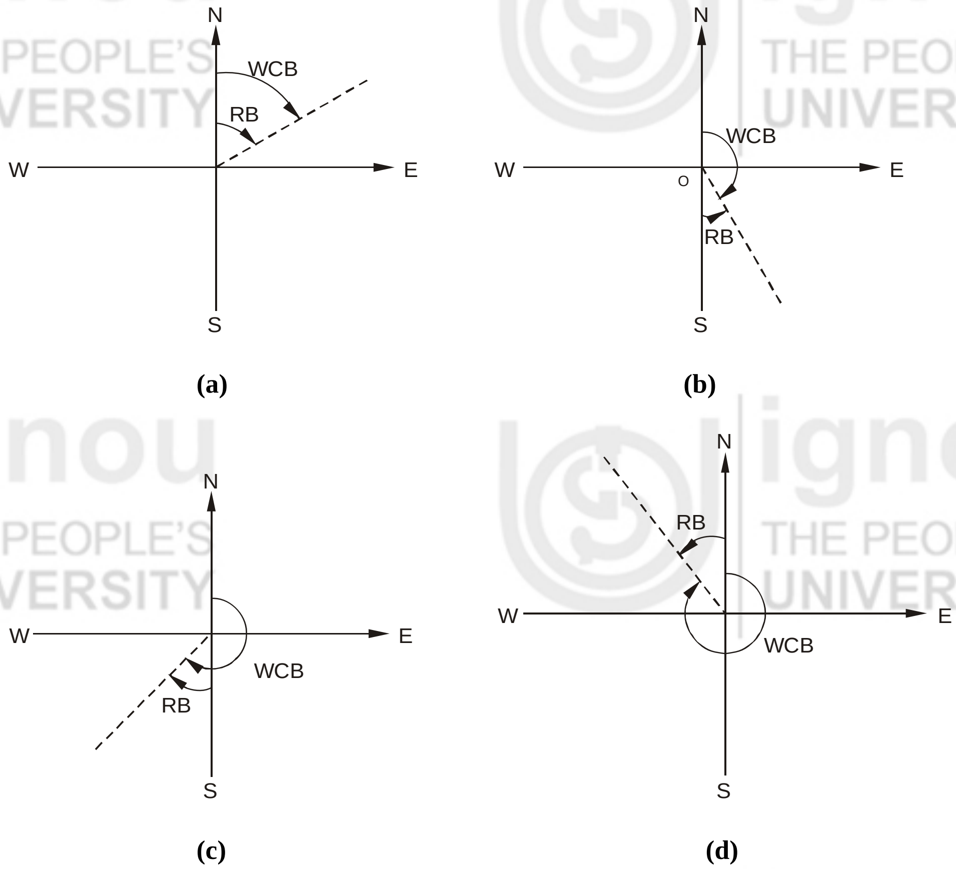


Figure 3.12 : *WCB* from *RB*

Solution

(a) *RB* = N 68° 32′ E

First Quadrant *WCB* = *RB*

= 68° 32′

(b) *RB* = S 37° 16′ E

Second Quadrant

$$WCB = 180^\circ - RB$$

$$= 180^\circ - 37^\circ 16'$$

$$= 142^\circ\ 44'$$

(c) *RB* = S 54° 32′ W

Third Quadrant

$$WCB = 180^\circ + RB$$

$$= 180^\circ + 54^\circ\ 32'$$

$$= 234^\circ\ 32'$$

(d) *RB* = N 39° 52′ W

Fourth Quadrant

$$WCB = 360^\circ - 39^\circ\ 52'$$

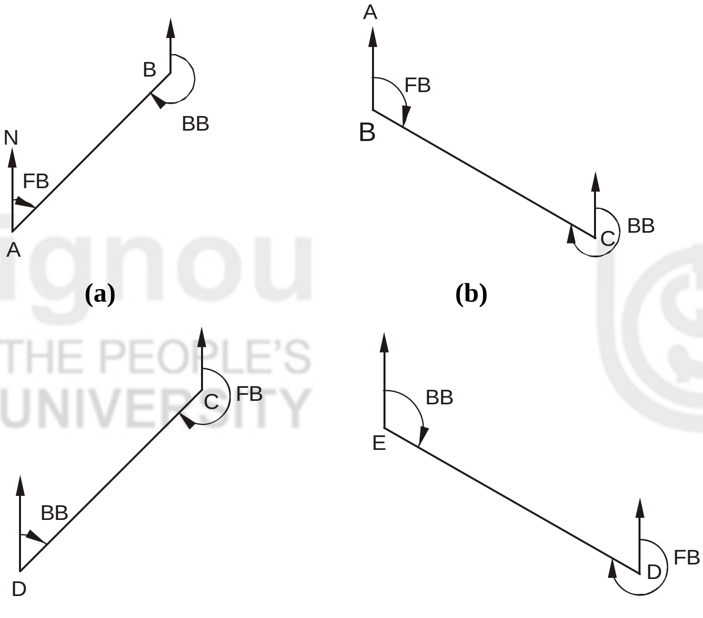
$$= 320^\circ\ 08'$$

Example 3.3

Following are the observed fore bearings of the lines. Find their back bearings :

AB 42° 34′, *BC* 163° 46′

CD 204° 29′, *DE* 337° 52′



(a) (b) (c) (d)

Figure 3.13 : *BB* from *FB*

Solution

(a) *FB* of *AB* = $42^o\ 34'$

Back bearing of line *AB*

= Fore bearing of *AB* + 180^o

= $42^o\ 34' + 180^o$

= $222^o\ 34'$

(b) *FB* of *BC* = $163^o\ 46'$

Back bearing of line *BC*

= Fore bearing of *BC* + 180^o

= $163^o\ 46' + 180^o$

= $343^o\ 46'$

(c) *FB* of *CD* = $204^o\ 29'$

Back bearing of line *CD*

= Fore bearing of *BC* – 180^o

= $204^o\ 29' - 180^o$

= $24^o\ 29'$

(d) *FB* of *DE* = $337^o\ 52'$

Back bearing of line *DE*

= Fore bearing of *DE* – 180^o

= $337^o\ 52' - 180^o$

= $157^o\ 52'$

Example 3.4

Find the angle between lines *OA* and *OB* in following cases where the respective bearings are :

(a) $37^o\ 10'$ and $316^o\ 28'$

(b) $16^o\ 34'$ and $139^o\ 43'$

(c) $118^o\ 12'$ and $287^o\ 54'$

Solution

[**Rule :** When bearing of two lines as measured from point of intersection of lines, i.e. from *O*, and lines *OA* and *OB* are given, subtract smaller from greater. The difference will be interior angle if it is less than 180^o and exterior angle if it is more. Interior angle will then be (360^o – exterior angle).]

(a) *OA* = $37^o\ 10'$, *OB* = $316^o\ 28'$

Included angle = $316^o\ 28' - 37^o\ 10'$

= $279^o\ 18' > 180^o \Rightarrow$ Exterior angle

Interior angle *AOB* = $360^o - 279^o\ 18'$

= $80^o\ 42'$

(b) *OA* = $16^o\ 34'$, *OB* = $139^o\ 43'$

Included angle = $139^o\ 43' - 16^o\ 34'$

$= 123^o\ 09' < 180^o \Rightarrow$ Interior angle

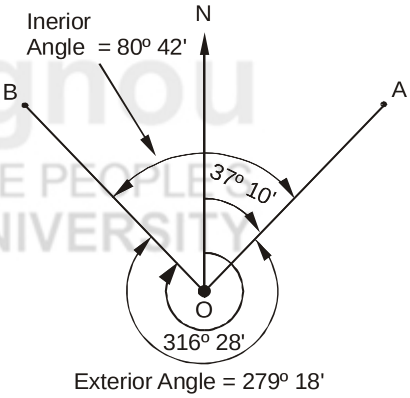
Interior angle $= 123^o\ 09'$

(c) $OA = 118^o\ 12'$, $OB = 280^o\ 54'$

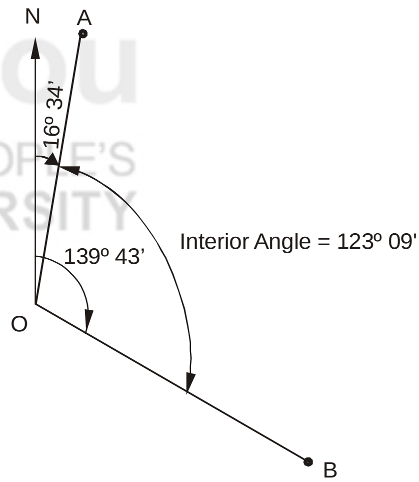
Included angle = $280^o\ 54' - 118^o\ 12'$

$= 162^o\ 42' < 180^o \Rightarrow$ Interior angle.

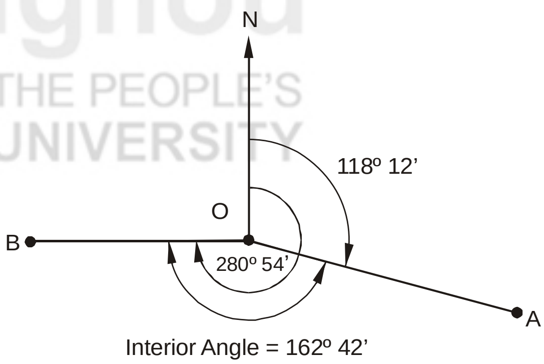
Interior angle $= 162^o\ 42'$.



(a)



(b)



(c)

Figure 3.14 : Included Angles

Example 3.5

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The fore bearings of line *AB* and *BC* are given. Calculate the included angle between them.

(a) *FB* of *AB* = 108^o 24′, *FB* of *BC* = 210^o 18′

(b) *FB* of *AB* = 16^o 36′, *FB* of *BC* = 323^o 43′

(c) *FB* of *AB* = 196^o 37′, *FB* of *BC* = 263^o 19′

Solution

(a) Included angle *ABC* = ± (*FB* of *BC* – *BB* of *AB*)

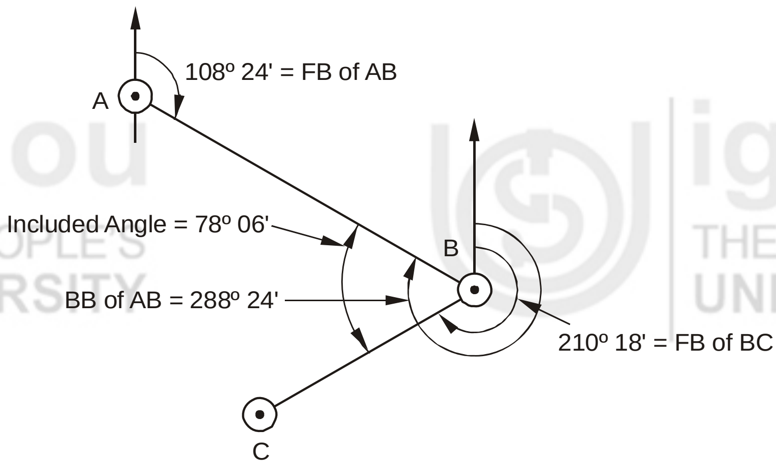
Back bearing of *AB* = 108^o 24′ + 180^o = 288^o 24′
∠ *ABC* = 288^o 24′ – 210^o 18′ = 78^o 06′

(b) *FB* of *BC* = 323^o 43′

BB of *AB* = 16^o 36′ + 180^o = 196^o 36′

Included angle *ABC* = 323^o 43′ – 196^o 36′

= 127^o 07′



(a)

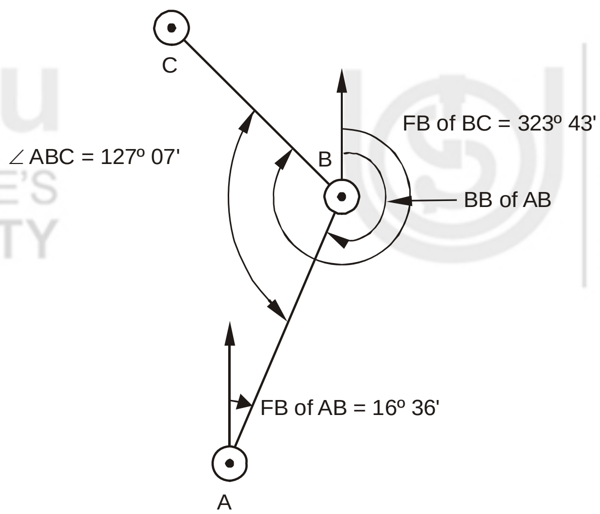


Figure 3.15 (b)

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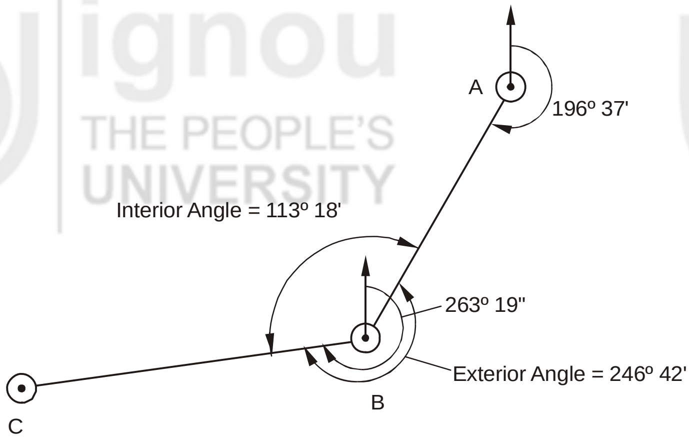

Figure 3.15 (c)

(c) *FB* of *AB* = 196° 37′, *FB* of *BC* = 263° 19′

BB of *AB* = 196° 37′ – 180°

= 16° 37′

Included angle *ABC* = 263° 19′ – 16° 37′ = 246° 42′ >180° exterior angle.

Interior angle *ABC* = 360° – 246 ° 42′

= 113° 18′.

Example 3.6

During the compass survey a traverse *ABCDE* was run. The bearings as measured are recorded in table given below. Compute the interior angle of traverse. Also calculate closing error if any.

Side	*AB*	*BC*	*CD*	*DE*	*EA*
FB	106° 19′	27° 06′	279° 42′	193° 17′	126° 32′
BB	286° 19′	207° 06′	99° 42′	13° 17′	306° 32′

Solution

(a) Back bearing of *AB* = 286° 19′

Fore bearing of *BC* = 27° 06′

Included angle *ABC* = 286° 19′ – 27° 06′ = 259° 13′ > 180° Exterior angle.

∠ *B* = 360° – 259°13′ = 100⁰ 47′ Interior angle.

(b) Back bearing of *BC* = 207° 06′

Fore bearing of *CD* = 279° 42′

Included angle = Difference of bearings; ∠ *C* = 72° 36′ < 180° Interior angle.

(c) Back bearing of *CD* = 99° 42′

Fore bearing of *DE* = 193° 17′

Included angle = Difference of bearing; ∠ *D* = 93° 35′ < 180° Interior angle.

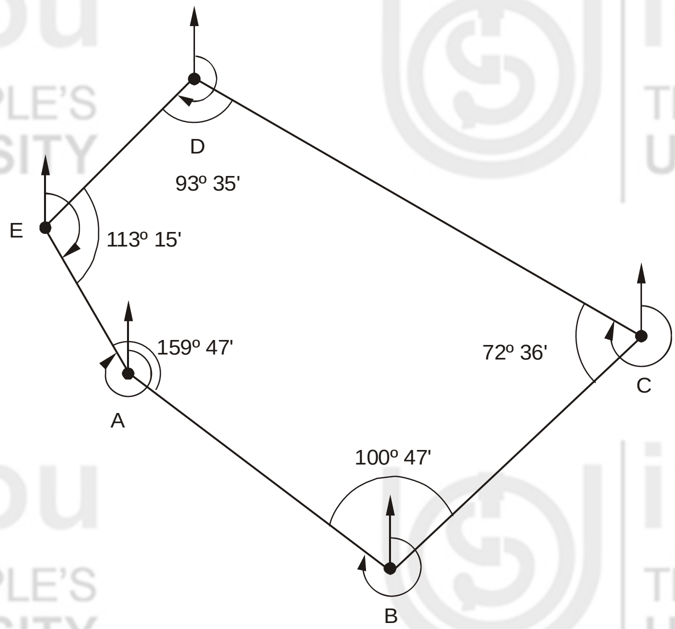

Figure 3.16

(d) Back bearing of $DE = 13^{o}\ 17'$

Fore bearing of $EA = 126^{o}\ 32'$

Included angle = $\angle E$ = Difference of bearings
$= 113^{o}\ 15' < 180^{o}$ (Interior angle).

(e) Back bearing of $EA = 306^{o}\ 32'$

Fore bearing of $AB = 106^{o}\ 19'$

Included angle = $\angle A$ = Difference of bearings
$= 200^{o}\ 13' > 180^{o}$ (Exterior angle).

$= 360^{o} - 200^{o}\ 13' = 159^{o}\ 47'$ (Interior angle)

Check $\Sigma \angle = \angle A + \angle B + \angle C + \angle D + \angle E$

$= 159^{o}\ 47' + 100^{o}\ 47' + 72^{o}\ 36' + 93^{o}\ 35' + 113^{o}\ 15' = 540^{o}\ 00'$

$(2N - 4) \times 90^{o} = (10 - 4) \times 90 = 540^{o}$

$\therefore$ There is no closing error in the traverse.

Example 3.7

Measurements of bearings, while running a traverse *ABCDE* are recorded in table given below.

Side	*AB*	*BC*	*CD*	*DE*	*EA*
FB	$191^{o}\ 45'$	$39^{o}\ 30'$	$22^{o}\ 15'$	$242^{o}\ 45'$	$330^{o}\ 15'$
BB	$13^{o}\ 0'$	$222^{o}\ 30'$	$200^{o}\ 30'$	$62^{o}\ 45'$	$147^{o}\ 45'$

It is suspected that reading at some survey stations were effected by local attraction. Locate the stations affected by local attraction and find the corrected bearing of the lines.

Solution

The first step is to obtain the difference between FB and BB of every line and obtain its deviation from 180^o.

Line	*AB*	*BC*	*CD*	*DE*	*EA*
Difference between *FB* and *BB*	$178^o\ 45'$	$183^o\ 00'$	$178^o\ 15'$	$180^o\ 00'$	$182^o\ 30'$
Deviation	$-1^o\ 15'$	$+3^o\ 00'$	$-1^o\ 45'$	$0^o\ 0'$	$2^o\ 30'$

It is thus found that line *DE* has a perfect difference of 180^o between fore bearing and back bearing. It can be concluded that station *D* and station *E* are free from local attraction.

Observed fore bearing *EA* and back bearing *CD*, are assumed to be correct. Since deviation at A is $+ 2^o\ 30'$. The needle is deflecting to an amount of $2^o\ 30'$ from true north towards east.

Correction to all readings of bearing taken at station *A*, therefore, shall be $+ 2^o\ 30'$, i.e. fore bearing of *AB* at *A* is corrected to $191^o\ 45' + 2^o\ 30' = 194^o\ 15'$ and the back bearing of line *EA* at $A = 147^o\ 45' + 2^o\ 30' = 150^o\ 15'$.

The corrected back bearing of line *AB* would be = Corrected *FB* of *AB* at $A - 180^o = 194^o\ 15' - 180^o = 14^o\ 15'$.

However, the observed back bearing of line *AB* at station *B* is 13^o. This indicate that station *B* is also affected by local attraction needle deflecting east wards by an amount $1^o 15'$ from true north. $(14^o\ 5' - 13^o = + 1^o 15')$

Bearings at *B* are required to be corrected by $+ 1^o 15'$.

Hence the fore bearing of *BC* as corrected would be $39^o\ 30' + 1^o\ 15' = 40^o\ 45'$.

The corrected back bearing of *BC* at *C* would be $40^o\ 45' + 180^o = 220^o\ 45'$.

The observed back bearing of line *BC* at *C* is however $222^o\ 30'$. This concludes that needle at *C* is deflected $(220^o\ 45' - 222^o\ 30') = - 1^o\ 45'$ from true north. Negative sign indicting deflection towards west.

The corrected fore bearing of line *CD* would be $22^o\ 15' - 1^o\ 45' = 20^o\ 30'$

Corrected back bearing at *CD* at station *D* would be $20^o\ 30' + 180^o = 200^o\ 30'$.

The observed back bearing of *DC* at $D = 200^o\ 30'$ giving a zero deviation at *D* indicating station *D* is free from local attraction. Similarly station *E* will also be free from local attraction.

The results can be tabulated as follows :

Line	Observed		Deviation/ Correction	Corrected		Remarks
	FB	*BB*		*FB*	*BB*	
AB	$191^o\ 45'$	$13^o\ 0'$	$+ 2^o\ 30'$ at A	$194^o\ 15'$	$14^o\ 15$	A, B and C stations are affected by local attraction while station D and E are free.
BC	$39^o\ 30'$	$222^o\ 30'$	$+ 1^o\ 15'$ at B	$40^o\ 45'$	$220^o\ 45'$	
CD	$22^o\ 15'$	$200^o\ 30'$	$- 1^o\ 45'$ at C	$20^o\ 30'$	$200^o\ 30'$	
DE	$242^o\ 45'$	$62^o\ 45'$	0 at D	$242^o\ 45'$	$62^o\ 45'$	
EA	$330^o\ 45'$	$147^o\ 45'$	0 at E	$330^o\ 15'$	$150^o\ 15'$	

SAQ 3

The following fore and back bearings were observed in an open traverse.

Line	*FB*	*BB*
1-2	02^o 15′	182^o 15′
2-3	174^o 15′	354^o 00′
3-4	223^o 00′	42^o 45′
4-5	166^o 30′	346^o 45′

Which stations are affected by local attraction and how much? Determine the true bearings of the line if the magnetic declination in the survey area is 02^o10′ E.

3.6 SUMMARY

In this unit, you have studied about the compass and its use for bearings of measuring survey lines. The angular measurements are carried out with prismatic compass that uses a magnetic needle and the bearings of survey lines are measured with reference to magnetic meridian. Such bearings are called magnetic bearings. However, on earth the true north (geographical north) is different from magnetic north. The difference between true N-S axis and magnetic N-S axis is called declination. This declination varies from place to place on surface of earth and also on time of observation. Hence, the correct measurements of angles would be to obtain bearing of survey lines with reference to true N-S axis. Such bearings are termed as true bearings. However, true bearing can only be made with the help of astronomical surveying which is tedious, time consuming and costly for engineering applications. Magnetic bearings which can be obtained easily at very reduced cost with the help of simple instruments like magnetic compass are considered accurate enough for survey of small areas.

Procedures of making angular measurements, the errors involved and method of corrections are also discussed in detail. You can now conduct a simple chain and compass survey of the area, which is fast and sufficiently accurate method of surveying for most of the engineering applications.

3.7 ANSWERS TO SAQs

SAQ 1

(b) True bearing = Magnetic bearing + Declination

$= 210^o + (-4^o) = 206^o$

(–ve sign as declination is westward)

Present magnetic bearing = True bearing – Declination

$= 206^o - 10^o = 196^o$

True bearing = 206^o, Present magnetic bearing = 196^o

SAQ 3

Stations 3, 4 and 5 are affected by the local attraction, Error at 3 is + 15′ and at 4 is + 30′, True bearings are : 04^o 25′, 176^o 25′, 225^o 25′, 169^o 10′.