# CHART WORK

## Basic Concepts & Miscellaneous Calculations

Capt. Sudhir Singh Chaudhari
Nautical Officer & Lecturer
L.B.S. College of
Advanced Marine Studies & Research



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॥ वक्रतुण्ड महाकाय सूर्यकोटि समप्रभ ॥
॥ निर्विघ्नम् कुरुमेदेव सर्व कार्येषु सर्वदा ॥

*Dedicated to*

*Those who sowed the seeds of knowledge in me ....*
*..... my beloved parents*

**CAPT. H. SUBRAMANIAM,**
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M.I.Mar. Tech. M.I.Met.,S., Extra Master

Principal
L.B.S. College of Advanced
Maritime Studies & Research,
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Hay Bunder, Mumbai 400033
22nd November 1997.

# *Foreword*

Capt. S.S. Chaudhari has been my student in this college for all his certificates of competency - Second Mate F.G. in 1982, First Mate F.G. in 1984 and Master F.G. in 1986.

An ex-cadet of the 1978-79 batch of the Training Ship 'Rajendra', he served with M/s Scindia Steam Navigation Company Limited, one of the finest companies at that time, known for excellent traditions and dedication of its officers. He obtained command of a foreign flagged merchant ship in 1990.

He is now a Nautical Officer, teaching various subjects to merchant navy officers, in this college. He is popular among the students for his cheerful disposition and dedication to his work.

In his first venture at writing a book, he has chosen the subject of Chartwork. The book is in 'question and answer' form. He has prepared an imaginary chart by himself that would accompany the book. He has also included the topics of 'Passage Planning' and 'Tides'.

Being an author myself, I understand the hard work invloved and the courage required to write a book on a technical subject.

Knowledge is one thing that can be given continuously and endlessly without any loss to the giver!

I wish Capt. Chaudhari all success in this venture.

(Capt. H. Subran

## Acknowledgment.....

I am extremely thankful to the Ex-Principal **Capt. H. Subramaniam,** who has been a wellwisher right through, gave many valuable suggestions from his rich experience and always encouraged me in this project

I owe much to my wife **Rita** for all her support & encouragment.

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## ABBREVIATIONS USED IN THIS BOOK

| | | | |
|---|---|---|---|
| Admiralty | Adm | Half Ahead | H/ahd |
| Admiralty Distance Tables | ADT | Height | ht |
| Admiralty List of Lights | ALL | Height of eye | HE |
| Admiralty List of Radio Signals | ALRS | High Water | HW |
| Admiralty Sailing Directions | ASD | Highest Astronomical Tide | HAT |
| Admiralty Tide Tables | ATT | Horizontal | hor |
| Altitude | alt | Horizontal parallax | HP |
| Angled | ∠ed | Horizontal Sext angle | HSA |
| Annual Summary of Adm Notices to Mariners | ANM | Hour angle | HA |
| Answer | Ans | Hours | h |
| Apparent Altitude | AA | Inshore Traffic Zone | ITZ |
| Approximate/ly | aprox | International Association of Lighthouse Authorities | IALA |
| Astronomical | astro | International Hydrographic Organization | IHO |
| Base line | B-L | International Maritime Organization | IMO |
| Beacon | Bn | Kilohertz | kHz |
| Bearing | brg | Kilometres | km |
| British Admiralty | BA | Knots | kn |
| Chart Datum | CD | Lane Identification | LI |
| Correction | corrn | Latitude | lat |
| Course | Co | Light | Lt |
| Course Made Good | CMG | Local Time | LT |
| Date of Printing | DOPr | Longitude | long |
| Date of Publication | DOP | Lowest Astronomical Tide | LAT |
| Declination | dec | Magnetic | (M) |
| Deep Water (Route) | DW | Mean High Water | MHW |
| Departure | dep | Mean High Water Neaps | MHWN |
| Deviation | Dev | Mean High Water Springs | MHWS |
| Diff of long | d'long | Mean Higher Low Water | MHLW |
| Difference | diff | Mean Level | ML |
| Direction | Dir | Mean Low Water Neaps | MLWN |
| Distance | dist | Mean Low Water Springs | MLWS |
| Distance Made Good | DMG | Mean Lower High Water | MLHW |
| Distance obtained by Radar | Ra | Mean Lower Low Water | MLLW |
| Distance over Ground | DoG | Mean Sea Level | MSL |
| Distance to go | DTG | Meridian | mer |
| DR position | DR | Meridian passage | mer pass |
| Electronic Bearing Line | EBL | Metres | m |
| Estimated position | EP | Microseconds | µs |
| Expected time of arrival | ETA | Minutes | min |
| Foot(feet) | ft | Nautical miles | M |
| Greenwich mean time | GMT | Nautical Publication | NP |
| Geographical Range | GR | New Edition | N Ed |
| Global Positioning System | GPS | Nominal Range | NR |
| Great Circle | GC | North | N |
| Group Repetition Interval | GRI | Notices to Mariners | NM |
| Guide to Port Entry | GPE | Number | No |
| Gyro | G | Observed altitude | Obs alt |
| Ocean Passages of World | OPW | Simple Harmonic Method | SHM |
| Officer on Duty | OOD | South | S |

| | |
|---|---|
| Mean Higher High Water | MHHW |
| Parallax in altitude | Plx in alt |
| Path Propagation Correction | PPC |
| Perpendicular | ⊥ar |
| Point | Pt. |
| Position | pos |
| Position line | PL |
| Preliminary (correction) | (P) |
| Present Luminous Range | PLR |
| Question | Q |
| Rules of Road | ROR |
| Secondary Port | Sec Port |
| Sextant altitude | Sext alt |
| Standby Engines | SBE |
| Starboard | Stbd |
| Temporary(correction) | (T) |
| Traffic Separation Scheme | TSS |
| True | T. |
| True Altitude | T alt |
| UK Hydrographic Office | UKHO |
| Variation | Var |
| Vertical Sext angle | VSA |
| Vessel Traffic Management System | VTMS |
| Vessel Traffic System | VTS |
| Weekly Notices to Mariners | WNM |
| Zenith distance | ZD |

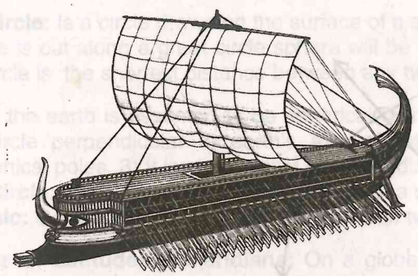


## CONTENTS

**Chapter wise syllabus, various grades**

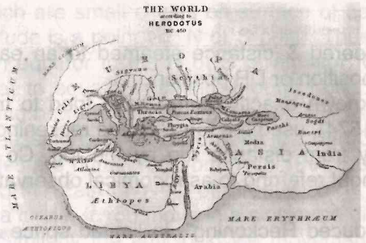
| Sr.Nr. | Grades | Chapters |
|---|---|---|
| 1. | 3 month Pre-Sea Course | 1-6, 8-13, 31, 32, 34(only std ports) |
| 2. | NCV- NWKO | 1-12, 14, 15, 26, 30-32, 34 & 35 (Indian ports only) |
| 3. | Second Mate FG | 1-21, 25, 26, 31, 32, 34, 35, 37 |
| 4. | Phase I FG | All chapters, Ch 24 (A only) Ch 38 (part only) |
| 5. | B.Sc Nautical | As per syllabus |





**Greek Navigators:** *Greeks were one of the first ones to understand the relation ship between the length of daylight & latitude of place for a given month. This was used to determine latitude of place.*

*Pic. Greek Trireme, L = 55m (400 BC)*




**Herodotus:**

*Figure shows a map compiled by Herodotus in 450 BC. The known world consisted of Mediterranean sea surrounded by three land masses viz Libya, Europe & Asia. These masses were surrounded by extremely large sized oceans till the end of the world.*

*[Pic. The world by Herodotus]*

# Chapter 1. Position Coordinates & A Few Chart Types

**POSITION:**

Every point on earth's surface has its own 'positional identity'. The coordinates of any position can uniquely represent its location. Position of any place may also be indicated wrt some reference point, or a light house etc.

Position on earth can be described wrt

01. Greenwich Meridian, (East or West of it) & Equator, (North or South of it). e.g. 12°14'N, 015°18'E.

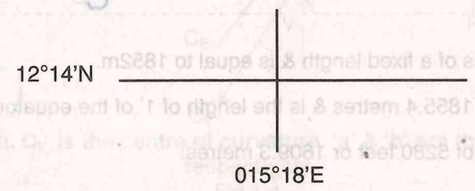



Fig.1.1

02. A known point, giving bearing & distance off from that point. e.g. ship in a position, with Sunk Rock beacon bearing 222°T x 4.1M.

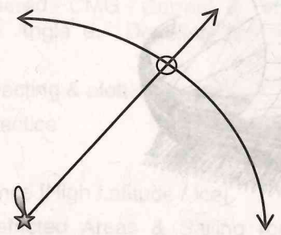


Fig.1.2

**DR Position:** Position obtained by applying course steered & distance steamed to an earlier known position (during any passage), is called dead reckoning position or DR position.

How the term 'Dead Reckoning' originated is not known exactly, some have tried to trace history behind it. Willium Bourne in his "Regiment of Sea"(year 1574), used the term "deade reckening", (which in those days meant), estimation of ship's position solely from distance run by the log, Co steered by compass, corrected for variation, current & leeway & without referring to astronomical observations.

Some believe that, the term was derived from "Deduced Reckoning". In limited space available in logbook, Deduced was written as Ded, which gradually got converted to Dead. DR position is indicated by a cross.

**Observed Position:** Ship's position determined from visual bearings, shore objects, radio bearings, electronic position fixing systems & celestial bodies is known as observed position. Enclosing a dot within a circle marks observed Pos. Thus:

Fig. 1.3

**Estimated Position:** Is the position obtained by applying Co steered, distance steamed & all known factors affecting position of ship viz., wind, current, compass error to the earlier known position.

If DR is found after a run of x hours, then distance from that DR to the observed position at the same time is drift due to the wind & current for x hours.

## MEASUREMENT OF DISTANCE:

**Sea Mile:** Length of a sea mile in a latitude is the length of arc of the meridian there, which subtends an angle of 1' at own centre of curvature. Its value varies with latitude & the mean value at 45° is 1852.3 metres.

**International nautical mile:** Is of a fixed length & is equal to 1852m.

**Geographic Mile:** Is equal to 1855.4 metres & is the length of 1' of the equatorial arc.

**Statute mile:** Or land mile is of 5280 feet or 1609.3 metres.

## DIRECTION:

The true direction between two points is indicated by the shortest drawn line or a great circle between the two points.



**True Bearing:** Of an object is a clockwise measure between the meridian & the direction of that object.

## SOME TERRESTRIAL TERMS:

**Great circle:** Is a circle drawn on the surface of a sphere, the plane of which passes through its centre. If a sphere is cut along a great circle sphere will be divided in two equal halves. Distance measured along great circle is the shortest distance between any two points on it.

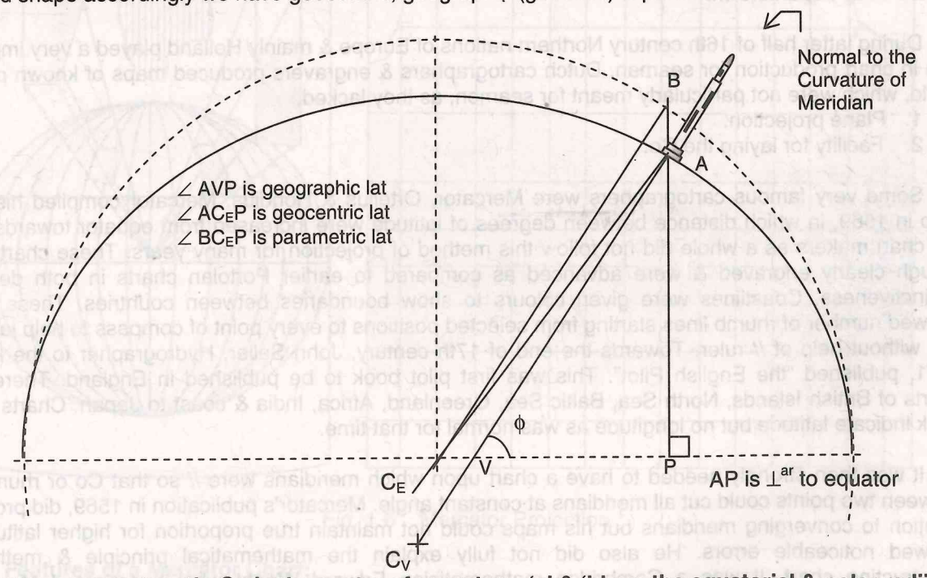
**Note:** If the earth is assumed to be spherical then: Equator is great circle on earth's surface. 1) It is a great circle perpendicular to earth's axis of rotation. 2) It is also a great circle equidistant from geographical poles. 3) It is also a great circle dividing earth in to Northern & Southern Hemisphere.

**Small Circle:** Is a circle drawn on the surface of a sphere whose plane does not pass through its centre.

**Geodesic:** Geodesic is the shortest line between two points on the spheroidal earth.

**Parallels of Latitudes & Meridians:** On a globe we see North & South hemispheres are horizontally segmented by small circles, whose planes are // to the plane of equator. These represent parallels of latitude, which are small circles on surface of earth, numbered in degrees from 0° (the equator) to 90° (the 90° latitude is a point viz. N or S pole). Thus value of latitude is a measure of angular distance of a parallel from equator to the N or S of equator. Globe is also seen segmented by several great circles perpendicular to equator, running through poles. These represent meridians. Meridians are semi great circles running between the N S poles. Meridians are identified by a number given to them i.e. longitude. A meridian passing through Greenwich is called Greenwich meridian. Longitude of Greenwich meridian is 0°. Longitudes are numbered from 0° to 180° E or W of Greenwich. Longitude tells us as to how much a position is to the East or West of Greenwich. If you see the globe from top of N pole then equator will appear like a circle. If you move in a clockwise direction along this circle, the direction of motion is called Westward. Similarly the anticlockwise movement is Eastward. There are 180 meridians to the East & equal number of meridians to the West of Greenwich meridian.

**Latitude of a place:** In broad terms is the angular distance north or south of equator. Earth has an oblate spheroid shape accordingly we have geocentric, geographic (geodatic) & parametric latitude.




**$C_E$ is the centre of earth. $C_V$ is the centre of curvature. 'a' & 'b' are the equatorial & polar radii respectively**

Fig 1.4

**Geocentric latitude:** Angle made between a line drawn from a point on surface of earth to the centre of earth & plane of equator is the geocentric latitude of that place.

**Geographic or Geodetic latitude:** Angle made between a line drawn from a point on surface of earth to the centre of curvature of that part of meridian & plane of equator is called geodatic or geographic latitude of that point.

**Parametric Latitude:** Is equal to $\tan^{-1}\left(\frac{b}{a}\right)\tan\phi$ where $\phi$ is the geographic latitude of that place.

Position on surface of earth can be completely represented by its latitude & longitude. Thus the position, 20°10' N 105°12'E is 20°10' to the North of equator & 105°12' to the East of Greenwich. No two points on the surface of earth can have same latitude / longitude.

## CHARTS:

A chart is diagrammatic and systematic representation of a particular description or subject, so that the charted information is easily understood & can be viewed at a glance. Charts are the sea maps. Maps have been in existence from time immemorial, whereas sea charts came in to being quite recently. This was the result of man's search for new horizons for trade, discovery & his will to acquire new lands. It is said that the first of the sea charts were made for Mediterranean.

Variety of information, which can be useful to a navigator, was compiled from time to time. Greeks were one of the earliests to compile & prepare the documents similar to Sailing Directions. The compilations were called 'Peripli'. These were accompanied by charts.

Hand drawn charts dating back to 14th century AD of commendable accuracy have been found. These are called 'Portolan Charts', drawn by draughtsmen & map makers of Italy. Later, they were made in Spain & Portugal too. Earlier instants of existence of charts are revealed in the recorded works of Guillaume de Nangis (1270 AD), where there is a mention of charts, showing approximate distance of nearest land.

Earlier charts were only made for Mediterranean, Black Sea, part of West Africa, Spain, France, British Island & North Sea. Coast was usually black. No colour was given to land or water. Small islands, rocks were given colours. Nothing much was done towards convex nature of earth, though the convexity of earth was not unknown.

During latter half of 16th century Northern nations of Europe & mainly Holland played a very important role in chart production for seaman. Dutch cartographers & engravers produced maps of known parts of world, which were not particularly meant for seamen, as they lacked,

1. Plane projection.
2. Facility for laying the Co.

Some very famous cartographers were Mercator, Ortelius & Hondius. Mercator compiled his world map in 1569, in which distance between degrees of latitude were increased from equator towards poles but chart makers as a whole did not follow this method of projection for many years. These charts were though clearly engraved & were advanced as compared to earlier Portolan charts in both details & distinctiveness. Coastlines were given colours to show boundaries between countries. These charts showed number of rhumb lines starting from selected positions to every point of compass to help laying of Co, without help of // ruler. Towards the end of 17th century, John Seller, Hydrographer to the King in 1671, published "the English Pilot". This was first pilot book to be published in England. There were charts of British Islands, North Sea, Baltic Sea, Greenland, Africa, India & coast to Japan. Charts in this book indicate latitude but no longitude as was normal for that time.

It was then strongly needed to have a chart upon which meridians were // so that Co or rhumb line between two points could cut all meridians at constant angle. Mercator's publication in 1569, did provide a solution to converging meridians but his maps could not maintain true proportion for higher latitudes & showed noticeable errors. He also did not fully explain the mathematical principle & method of constructing chart. It was a Cambridge mathematician Edward Wright who investigated Mercator's principles & gave them a sound mathematical base. In order to illustrate his method of depicting surface of a globe on a plane, Wright suggested to imagine a rectangular plane rolled around a globe until it formed a cylinder, enclosing globe & touching it at equator. Thus imagine a globe to swell like a bladder blown till every part of its surface except pole touches sides of cylinder. The impression of meridians & //



left on inner surface of rectangle would give set of perpendicular lines & features of earth distorted as per Mercator projection.

**Navigational Charts** represent features of earth on the flat paper & include the details of sea (whether underwater or surface), coast & land, which may be useful for navigational purpose.

Charts may be of different type viz. Mercator Charts, Gnomonic Charts, Plan Charts etc.

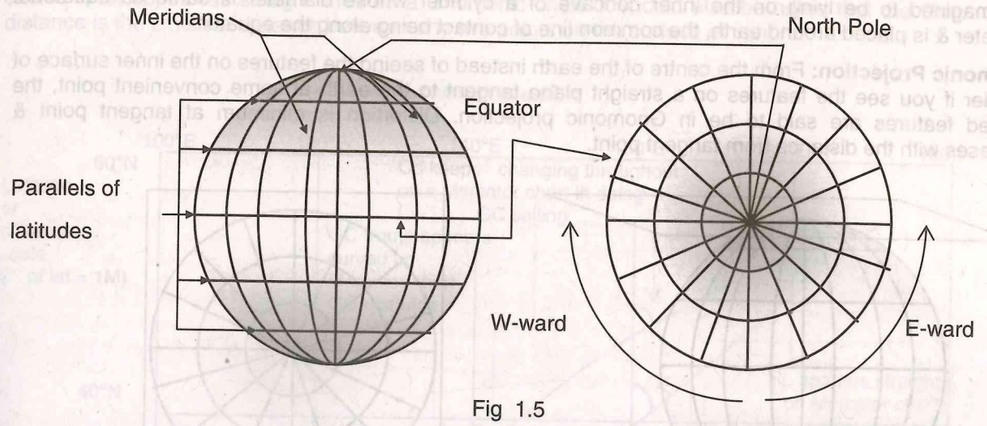



Fig 1.5

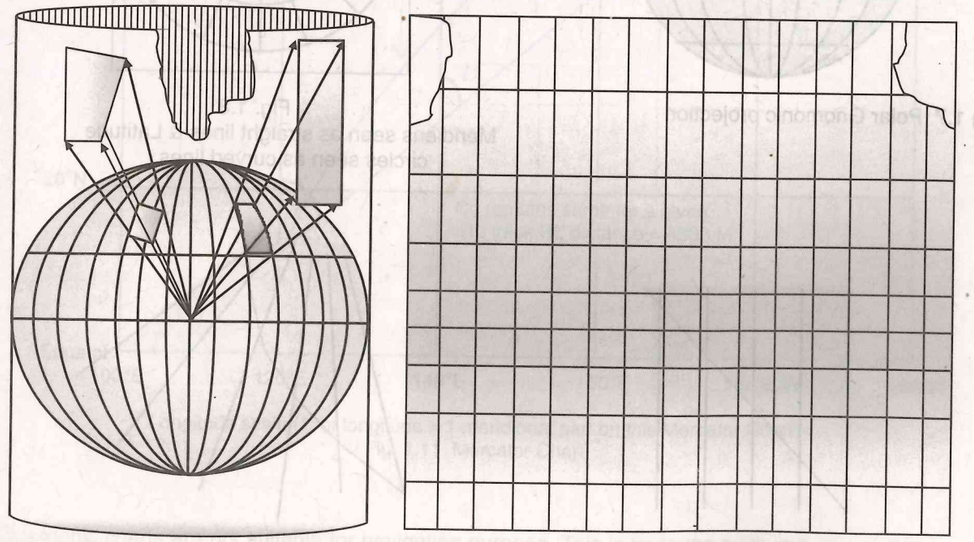


Fig. 1.6 Mercator Projection

**Salient Features of a Mercator Chart:**

1. Latitude scale can also be used to measure the distance between two positions on chart.
2. Parallels of latitudes & meridians are mutually perpendicular & straight lines. All parallels of latitudes run E-W & are // to each other. All meridians run N-S and are // to each other too. Thus parallel ruler can be used for transfer of position lines, for laying of course line, for plotting of given latitude & longitude & for reading the latitude or longitude of a given position.

3. Mercator projection is Orthomorphic. This means that scale of distance in all the directions around a point is constant. This helps in maintaining the shape of small portions of charted areas & relative direction of charted objects in the neighbourhood.

**Mercator Projection:** To understand the Mercator projection, imagine yourself to be at the centre of the earth. The earth is assumed to be transparent with the features on the surface of earth distinctly visible from centre. Instead of viewing the coastal features, latitudes, longitudes etc on the surface of earth, they are imagined to be lying on the inner concave of a cylinder whose diameter is same as equatorial diameter & is placed around earth, the common line of contact being along the equator.

**Gnomonic Projection:** From the centre of the earth instead of seeing the features on the inner surface of cylinder if you see the features on a straight plane tangent to the earth at some convenient point, the charted features are said to be in Gnomonic projection. Distortion is minimum at tangent point & increases with the distance from tangent point.

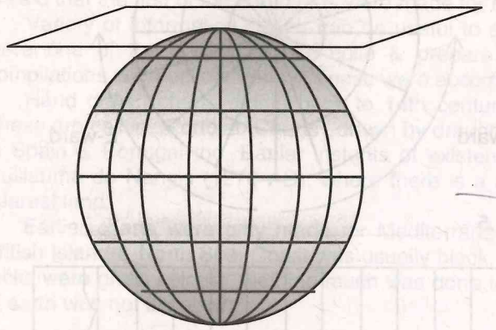


Fig 1.7 Polar Gnomonic projection

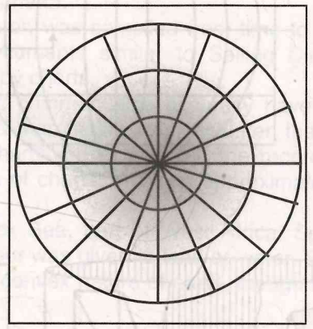
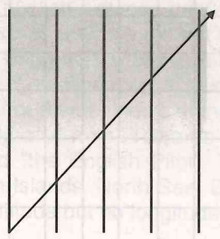
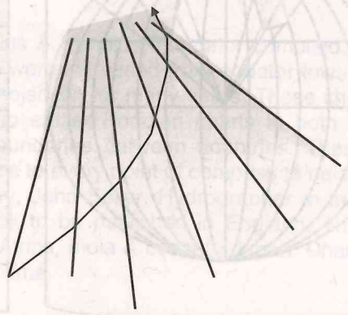


Fig. 1.8
Meridians seen as straight lines & Latitude circles seen as curved lines.



Rhumb line on a Mercator chart

Fig 1.9



Rhumb line on a Gnomonic chart

Fig 1.10



**Rhumb line:** is a line which when drawn on a chart makes equal angle to all meridians on the way.

- On Mercator chart it appears as straight line.
- On a Gnomonic chart, all 'rhumb-line courses' except north-south and east-west courses converge towards pole.

We know that the plane of a great circle passes through centre of sphere, hence all the great circles on the earth's surface when projected to a tangent plane will appear as straight lines. Due to this all great circles must appear as straight lines on a Gnomonic chart. It should also be noted that the Great circle distance is the smallest distance between any two points on the surface of sphere.

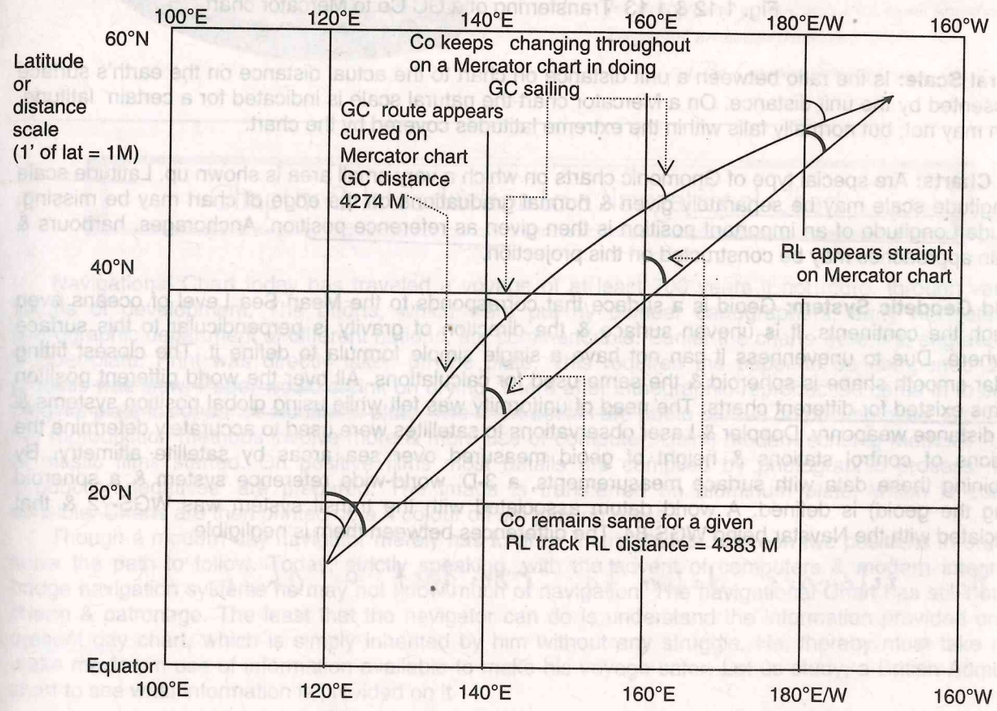



Fig. 1.11 Mercator Chart

Gnomonic charts are not suitable for navigation purpose. This is because a Rhumb course line would appear curved. Plotting of courses, plotting of bearings, use of compass rose & measuring distances on a Gnomonic chart would be inconvinient.

In spite of above difficulties, Gnomonic plotting sheets are very useful for finding out waypoints on a great circle route. Arrival & departure positions are joined by a straight-line, which is a great circle route between the two positions. At regular interval waypoints are chosen. Latitude - longitudes of these waypoints are read off & then transferred on a Mercator chart.(See fig 1.12 & 1.13)

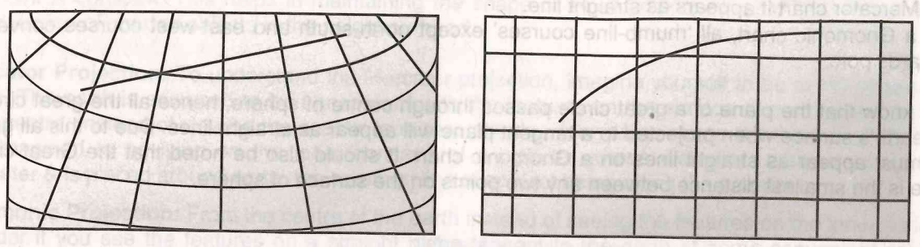


Fig. 1.12 & 1.13 Transferring of a GC Co to Mercator chart

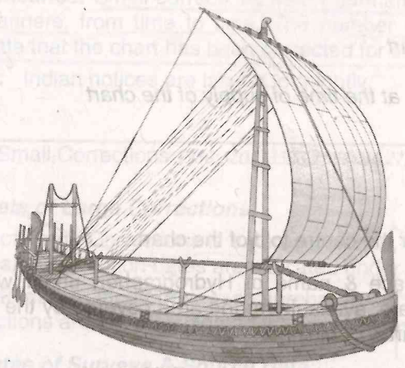
**Natural Scale:** Is the ratio between a unit distance on chart to the actual distance on the earth's surface represented by the unit distance. On a Mercator chart the natural scale is indicated for a certain latitude, which may not, but normally falls within the extreme latitudes covered by the chart.

**Plan Charts:** Are special type of Gnomonic charts on which a very small area is shown up. Latitude scale & longitude scale may be separately given & normal graduations on the edge of chart may be missing. Latitude Longitude of an important position is then given as reference position. Anchorages, harbours & certain approaches may be constructed on this projection.

**World Geodetic System:** Geoid is a surface that corresponds to the Mean Sea Level of oceans even through the continents. It is uneven surface & the direction of gravity is perpendicular to this surface anywhere. Due to unevenness it can not have a single simple formula to define it. The closest fitting regular smooth shape is spheroid & the same used for calculations. All over the world different position datums existed for different charts. The need of uniformity was felt while using global position systems & long distance weaponry. Doppler & Laser observations to satellites were used to accurately determine the positions of control stations & height of geoid measured over sea areas by satellite altimetry. By combining these data with surface measurements, a 3-D, world-wide reference system & a spheroid (fitting the geoid) is defined. A world datum associated with the transit system was WGS-72 & that associated with the Navstar being WGS-84. The differences between them is negligible.

It is the reference datum to construct a chart.





**Egyptians:** *Egyptians have significant contribution in development of art of shipbuilding. By 4000BC they were already making long narrow reed boats powered by a line of paddlers. By 3000 BC they were using sails. Planks of wood were now used to make ships for high seas. Initially ships were light only to navigate in river Nile, later the sea going ships had a kind of keel & athwartships ribs. Bow & stern had a heavy rope looped tightly around for strengthening. Tall sails were made broad at base large oars propelled from stern area.*

*[Pic. Egyptian Seagoing cargo ship, L = 40m (2500BC)]*

# Chapter 2. Introduction to a Navigational Chart

Navigational Chart today has traveled a voyage of at least 700 years if not more, through various stages of development. The efforts, which were put by pioneer cartographers, early navigators & hydrographic department of different nations, are commendable. Earlier the charts were first engraved on Copper-plate. Print was directly taken off the plate. This required the paper to be dampened & the process was slow. Paper would shrink on drying. There after Lithographic reproduction came in to being. Original plate is copper or aluminum plate. The chart details are photo printed on printing plate. Since 70s the reproduction methods involve more & more use of computer. Using modern scribing methods & use of plastic films started. On positive films most details are compiled by photographic process. Final 'production-negatives' are prepared. The image is transferred on aluminum plate, which is contact sensible. Charts are then printed on a 4 colour off set printing press.

Though a modern day navigator merely has to draw a straight line between two positions in order to know the path to follow. Today, strictly speaking, with the advent of computers & modern integrated bridge navigation systems he may not know much of navigation. The navigational Chart has still not lost charm & patronage. The least that the navigator can do is understand the information provided on the present day chart, which is simply inherited by him without any struggle. He, thereby must take must make maximum use of information available to make his voyage safer. Let us study, a British Admiralty chart to see what information is provided on it

## Understanding, information provide on a navigational chart

*Q2.1 where do you find the following on BA Chart. what is the significance of each?*

a. *Date of Publication*
b. *Date of printing*
c. *Date of new edition*
d. *Date & number of small correction*
e. *Date of large correction*
f. *Date of surveys of various portions of the chart / Source Data*
g. *Number of the chart*
h. *Date & number of Temporary & Preliminary notices*
i. *Title of the chart*
j. *Scale of the chart*

*k. Unit & reference datum regarding height & depth*
*l. Projection used*
*m. Remarks regarding navigational marks used on the chart*
*n. Plate dimensions*
*o. Latest notice to which a chart is attended for correction at the time of supply of the chart*
*p. Caution*
*q. Notation, "Satellite Derived Positions"*

***(a) Date of Publication (DOP):***

**DOP** is indicated outside the south border of the chart, near the centre fold of the chart..

**Significance:** Date of publication is indicated with place & name of Hydrographer, under whose authority the chart is published. The entire hydrographic data, available for the area covered by the chart is assembled & for the first time it is incorporated in the chart & published.

**Note:** When New Edition date is not found on chart, DOP is considered as New Edition date.
**e.g.**

'Published at Taunton 19th September 1978 under superintendence
of Rear Admiral D.W. Haslam ,Hydrographer of Navy'

***(b) Date of Printing (DOPr):***

DOPr is marked outside the north border towards the eastern corner of the chart in case of Indian Charts & on the reverse of the chart at thumb label next to the chart number & title in case of a BA chart.

**Significance:** It means that printout of the copy of chart was taken on this date. Small corrections for the period between the date of New Edition & DOPr are incorporated by chart printers. The record of the corrections is found at bottom left corner of the chart in the original print form.

**46.78** on Indian Chart, means the print out was taken on 46th day of the year 1978.

On BA Chart, the same is indicated as **'Printed on 15.02.1978'** or 'Printed February 1978'

***(c) Date of New Edition (N Ed):***

DON Ed is marked below the south border of the chart, to the right of 'Date of publication'.
**Significance:** When the chart is revised & modernized in style, an up-to-date edition is published.
**Note:**
(a) A chart is actually known by its new edition date as to whether it is valid or not.
(b) Entries regarding the small corrections subsequent to the date of new edition may appear at left hand corner, out side the south border of the chart. All the earlier corrections are incorporated in the new edition.
(c) The charts of the same number but having an earlier date of new edition stand canceled.
(d) A chart whose **DOPr** is same as date of new edition, will not have printed entries of small corrections.
(e) If a chart is printed say two years after the date of new edition then record of small corrections for that chart for a period between **DON Ed & DOPr is** found on the chart at the usual place, in printed form.

DOP ~~~~~~~~ New Editions 21st May 1982, 5th April 1986

***(d) Date & Number of Small Corrections:***

Details regarding the small corrections are found near the left hand corner under the southn border of the chart.



**Significance:** Small corrections mean permanent corrections, which are promulgated in Weekly Notices to Mariners, from time to time. The number of Notice along with the year is entered on the chart to indicate that the chart has been corrected for such notice.

**Note:** Indian notices are issued fortnightly.

Small Corrections *1986:3201, 3598 1987: 34,271,539,1098*

***(e) Date of Large Corrections:***

Date of Large Corrections is entered on chart, in the same area as N Ed dates. If N Ed date is indicated, then large correction dates are indicated under N Ed dates.

**Significance:** Incorporates comprehensive corrections. Since corrections are comprehensive these corrections are not promulgated through notices. Large corrections are discontinued now.

***(f) Dates of Surveys & Source Data:***

'Dates of Surveys' & 'Source Data' is found within the Source Data diagram, which is placed in some convenient part of the chart, not to obscure essential navigational information.

**Significance:** Different areas covered by the chart may have been surveyed;
(a) By different surveying authorities,
(b) At different times,
(c) Using different methods, techniques,
(d) On different scales.

The relevant details are indicated on the chart in the Source Data diagram. The user may be guided by above information as to the degree of reliability to place on the chart while navigating on it. The user is also aware as to which part of the chart area was surveyed more recently as compared to the other areas. Most of the earlier surveys were mainly exploratory, trying to discover new lands. Later surveys paid more attention to depths, used improved instruments & techniques.

Prior to 1864 AD British survey ships were sailing ships. There after the steam replaced sails. Prior to 1935 lead & lines were the only means of obtaining soundings. Later the echo sounders were introduced. Side Scan Sonar came into general use in British survey ships in 1973.

Earlier survey-ships assumed the maximum draft of 15m & did not foresee the deep drafted ships drawing up to 30 meters.

SOURCE DATA
(Government Chart Surveys)
a: 1:5000 to 1:25000.....1981-1984 b: 1:10,000 t 1:60,000...1971-1977
c: 1:5000 to 1:25000.....1984-1986 d: 1:10,000 t 1:50,000...1985-1988
e: 1:15000 ....1988-1989

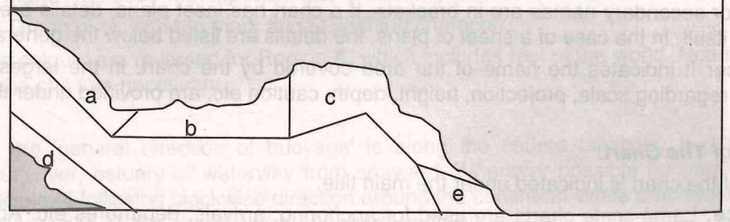



Fig 2.1

***(g) Number of The Chart:***

The number is found at the following places on a chart:

- Right hand bottom corner,
- Left hand top corner,
- Reverse side at thumb label.

Thus the number of a chart is printed on the label (the 'thumb label') on the back of chart sheet and also appears in two corners on the face of the chart.

**Significance:** Enables identification of any chart in the chart catalogue thus enabling one to quickly see the area covered by a chart. It also enables one to stow a chart in the folio in a systematic way & also pull out quickly whenever required for use. BA Charts are not numbered area wise. Thus charts BA 301 & BA 302 may not be for neighbouring geographical area & in fact the two areas may be quite remote from each other. *In the catalogue, against the chart number, it is indicated whether a chart is in the International Chart Series, or whether on ARCS or Small Craft Edition of the chart is Available.*

***(h) Date & Number of T & P Notices***

Date & Number of T & P Notices are recorded just under the entries made on the chart for small corrections. These entries are made in pencil & not in permanent ink.

**Significance:** Temporary corrections are the changes, which are of temporary nature only. These corrections are important however. Temporary corrections are made in pencil & not in permanent form because a subsequent notice is likely to cancel them at a later date. e.g. Insertion of buoys to mark a firing practice area which is likely to exist for a short while.

Preliminary corrections are the changes planned or proposed in near future in an area covered by the chart. These are made in pencil & the entries regarding the number & year of notice is also made in pencil. A permanent correction is promulgated after the proposed change has actually been carried out. Thus the permanent correction may be same or slightly different from the Preliminary Correction. Preliminary correction or notice will be canceled upon issue of relevant permanent notice to this effect.

e.g. Drawing a symbol indicating the position of a wharf which is proposed to be built soon or whose construction work is in progress.

***(i) Title of The Chart:***

The title of any chart is marked:

(a) At some convenient part of the chart in such a position that the essential navigational information is not obscured.

(b) On reverse side of the chart at the thumb label.

Alternative or secondary names are in brackets. If a chart has inset plans, details are listed below those of the chart itself. In the case of a sheet of plans, the details are listed below the general title of the chart.

**Significance:** It indicates the name of the area covered by the chart, in the largest letters. Important information regarding scale, projection, height, depth, caution etc. are provided under the title.

***(j) Scale of The Chart:***

The scale of the chart is indicated under the main title.

**Significance:** Large-scale charts are used for anchoring, arrivals, departures etc. Additional details are found on such charts. Certain details may be omitted from small & medium scale charts.



Medium scale charts are used in coastal navigation. Small-scale charts may not show many details & may not provide adequate information needed for safe navigation. Thus details regarding depth contours, underwater dangers, characteristics of lights etc. may be omitted from these charts. A small-scale chart however covers a large geographical area.

Hence while navigating on a medium scale chart both small scale & large-scale chart may be used as reference charts.

Ports & harbours are usually surveyed on a scale between 1:12,500 & 1:5000. Anchorage areas are surveyed on a scale of 1:25,000. A general coast survey for navigational purpose is made on a scale 1:50,000 & more.

Scale 1:20,000 at 20°00'N lat. or 1/20,000 at 20°00'N lat means 1 cm of chart in lat. 20°N actually represents 20,000 cm of length on earth surface at 20°N latitude.

***(k) Unit & Reference Datum of Height & Depths:***

Unit & Reference Datum of Height & Depths are indicated under the title.

**Significance:** Uniform datums wrt which the height & depths are indicated on the chart may be found under the title of chart. On BA charts the depths indicated are usually below one of the lowest of tide levels & is normally Lowest Astronomical Tide (LAT). In non tidal waters such as Baltic, chart datum is usually Mean Sea Level. Heights indicated are normally above Mean High Water Springs (MHWS).

Because of above datums the measured depths or heights at any given time should be normally more than charted depths & heights respectively.

On a metric chart heights & depths are given in meters. Shallow depths are indicated in meters & decimeters. On a fathom chart depths are given in fathoms. Heights are given in feet. Shallow depths are given in fathoms & feet.

***(l) Projection Used:***

The projection used for making the chart is indicated under the title.

**Significance:** Projection used on the chart may be Gnomonic, Mercator etc. depending on the scale & purpose for which the chart is made. (For details see a chapter on projection, later in this book).

***(m) Remarks Regarding Navigational Marks:***

Remarks Regarding Navigational Marks are made under or around the title.

**Significance:** IALA system has been implemented throughout much of the world. System provides five type of marks, viz. Lateral, Cardinal, Isolated danger, Safe water & Special marks. The marks may be used in combination on a chart. However the colours (red & green) are reversed in certain areas. The world is divided in two regions viz. Region A & Region B.

Region B includes North & South American & Japanese waters. Lateral marks in Region B buoys have colour and characteristics as follows:

(a) Starboard hand mark: Red buoy with top mark and of flashing character.

(b) Port hand mark: Green buoy with top mark and of flashing character.

The red & green colours are reversed for Region A, which includes rest of the world. Notation 'Region A or B' is found on the chart as necessary.

Conventionally the 'general direction of buoyage' is along the course taken by a mariner when approaching harbour, river, estuary or waterway from seaward. Wherever possible buoyage authorities have taken the principle of following clockwise direction around the continent. While proceeding along the general direction of buoyage in the channel, the starboard hand buoys have to be passed on starboard side & vice versa. On the reverse passage i.e. while going in a direction opposite to the general direction of buoyage the starboard hand buoy have to be passed on port side.

Thus it is very important to know the general direction of buoyage in an area, especially where the buoys mark a short stretch of deep water or shoal or where there are two channels emerging from same point.

The Buoyage Authorities determine the general direction of buoyage. The same can be found in Admiralty Sailing Directions or the relevant Admiralty chart, where the conventional direction of buoyage may be indicated by magenta arrow symbol.

Around the British Isle the general direction of buoyage runs N along the W coast and through the Irish Sea; E through the English Channel & N through the North Sea.

On many coasts and in some straits buoyage authorities have not yet established or promulgated general direction of buoyage, so it is not possible to chart the magenta symbol. This could be hazardous if a new danger were to be marked by Lateral Buoys.

***(n) Plate Dimensions:***

Plate dimensions are indicated at the bottom of chart in extreme right hand corner within a bracket.

e.g. (1130.0 x 640.0 mm)

**Significance:** Dimensions in inches or millimeters along with method of printing, type of plate & year is indicated. Dimension are compared with chart if any distortions of the chart is suspected.

*The size of the majority of Admiralty chart is about 980 x 640 mm, measured between the inner neat-lines; these charts are sold single-folded. A small number are half this size, corresponding to the folio size of 710 x 520 mm, and are sold unfolded. Increasingly, admiralty charts are produced to International AO size (841 x 1189mm).*

***(o) Latest notice or WNM which has been checked up for correction, at the time of supply of the chart:***

Indication is made on reverse of the chart at the thumb label.

**Significance:** Let's take a concrete example. Suppose a chart is published in 1958. Its **DON Ed** is **Jan 1985** **DOPr** is **Jan 1994.** The chart is purchased from the depot in Jan 1996.

The entry regarding small corrections made on the chart is as follows.

*LH Bottom Corner:* Numbers of weekly notices from Jan 1985 to Jan 1994 in original printed form. The relevant corrections are found on the chart in printed form. Additionally hand written entries for the corrections, between Jan 1994 and (say) 1236 of 1995 (May 1995)) are also found in this part of the chart.

*At thumb label on the reverse of the chart within the seal of the Chart Depot: An e*ntry, stating that the chart has been corrected up to BA notice 35 of 1996.

Meaning of the above entries is as follows:

a. The chart was first published in 1958.
b. The latest edition (current edition) is dated Jan 1985.
c. The authorized publishers have corrected the chart up to the DOPr (Jan 1994), before printing the chart.
d. The chart depot has arranged for the corrections (manually)) between date of printing & date of sale (Jan 96)
e. At thumb label the entry is up to notice no 35 of 1996, but the latest small correction entered on the chart is 1236 of 1995 (dated May,1995).
f. No correction was found for the period between May 1995 & Jan 1996.

**(p) Caution:** The notation 'caution' along with the warning is found under or around title & may also be found at a particular position on the chart to draw the attention of the mariner towards some important feature or danger. The feature or the danger may be about changing currents (magnitude & direction),



any unusual phenomenon in the area, limitations of the chart, possibilities of frequent cross ferries, former mines etc.

***(q) Notation 'satellite derived positions':***

*The notation 'satellite derived positions': is found close to the title.*

***Significance:** Positions obtained from satellite-based systems ( **NAVSTAR)** refer to **WORLD GEODETIC SYSTEM (WGS)** datum. Hence they can't be directly plotted on admiralty charts, which are normally referred to local datum. Charts of **DOP** or **DON Ed** after 1981 with scales equal to or more than 1:20,00000 Carry a note indicating the amount of shift between Satellite derived (WGS) positions & chart positions. In absence of such note, shift is assumed to be negligible.*

## To describe a particular copy of a chart

To describe a chart the following details must be indicated in given order:

a. The number of chart
b. Title
c. Date of publication
d. Date of new edition
e. Number or date of the last small correction.

## Special Purpose Charts

*Q.2.2 Write a short note on special purpose charts.*

**Ans:** Following are some of the special purpose charts:

**International Charts:** Cover large areas & are published by certain nations which are members of IHO. Two common small scale series are of 1:10 million scale & 1:3.5 million scale. The limits are internationally agreed. The member state will prefix the chart number by letters INT. e.g. INT 701. This chart when reprinted by Admiralty will be BA 4701. Sometimes prefix number is 40 instead of 4 depending on the scale of chart.

**Decca Charts:** Are normal navigational charts with electronically constructed Decca lattice overprinted on it. The charts are prepared for some of the coastal areas of world, where a Decca chain is installed. For such areas a non latticed navigation chart is also available. A Decca chart is prefixed by L(D) & the chain number. Thus:

***BA L(D2)1610 (Decca Chain 2E MP)*** will be marked on BA 1610 chart on which the Decca lattice of chain '2E MP' are overprinted.

**Loran C charts:** Are published by Admiralty & Defense Mapping Agency, Washington, for the areas covered by Loran C chain. Admiralty Loran C charts retain original BA number but are prefixed by L(L-C).

**Omega Charts:** Omega lattice may be overprinted on ocean charts meant for navigation. The chart retains original number but prefixed by L(Om), Omega system is discontinued now.

**Gnomonic Charts:** These charts are small in number & are meant to assist in great circle sailing. They cover Atlantic, Pacific & Indian Ocean except for equatorial belt.

**Routing Charts:** Are wonderful in providing information regarding current, ice & probable weather for any month, at a glance. Information is extremely useful for planning a voyage. These charts cover different oceans & are made to show weather conditions & loadline zones for each month. Thus a ship making a N Atlantic voyage on 25th January will find 'January & February routing charts' for North Atlantic extremely useful, not only for passage planning but also for reference during the passage. Prominent sea routes, prevailing currents, wind roses in different areas, storm tracks in past, probability of fog & gale, sea level temperature, air temperature, atmospheric pressure with isobars, in particular are provided on these charts & can be viewed at a glance. (See a description in the chapter on Passage Planning).

**General Bathymetric Charts of Oceans:** Different maritime nations are responsible by agreement reached through IHO, for coordinating the collection of ocean soundings to compile world wide bathymetric data. Areas of responsibility of different nations can be found in Adm Chart Catalogue.

**Ocean Sounding Charts:** Is a record of ocean soundings, compiled by hydrographic department from a variety of sources. These are reproduction of master copies of ocean sounding sheets, covering the world oceans.

**Ship's Boats charts:** Cover the oceans of world, showing the coastline, winds, currents, ice limits, isogonic lines. On the reverse one can find remarks on management of boats, use of charts, weather, current etc.

Other special purpose charts are

1. Star Charts & Diagrams,
2. Magnetic Force Charts,
3. Co Tidal & Co range Charts &
4. Instructional Charts.

### Reliability to place on a Chart

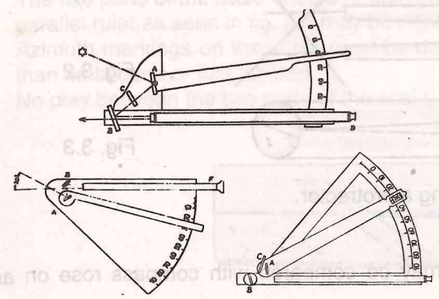
*Q.2.3 Discuss the factors, which must be considered, in placing the degree of reliability on a navigational chart.*

**Ans:** The charts have been made for every inch of sea but fact remains that a large portion of the underwater world still remains unexplored.

1. Seismic activity can give birth to new seamounts & rocks without any previous warning. There are several examples of accidental discovery of seamounts in the middle of oceans. Occasional soundings must therefore be taken even in safe & deep waters. Breaking of sea unusual sightings of sea ripples must be reported to Hydrographic Department. (See details regarding Hydrographic Note at end)
2. Coral reefs are reported to grow steadily causing a reduction in depth. An unmonitored area with coral reefs must be approached with caution.
3. Scale of chart must always conform to the need or purpose. Many dangers & features are omitted from small-scale charts. When navigating in traffic areas & critical areas, the chart of largest scale available must be used.
4. Date, Scale & Sophistication of survey methods are some other factors to be considered. Older surveys are less accurate as compared to modern surveys, using modern equipment for position finding. Earlier 15 metre was considered as safe depth of water as most ships had a maximum draft of 6 to 8 metre. "Time elapsed after survey date" is important consideration. Underwater areas undergo changes, which may be sudden or gradual. Ports & harbours are usually surveyed on a scale of between 1:12500 & 1:5000 & anchorages on scale only of 1:25000. A general survey of coast is done on a scale larger than 1:50,000. Depending on scale of survey, coarse or minute details are noted by a surveyor. Various survey details are available from the 'source data' displayed on the chart.
5. Dates & frequency of corrections & last correction date must always be considered to know how busy & critical the area under consideration is. A chart must be corrected with the latest correction issued.
6. Distortion of charts must be considered on old charts. Distortion on very old charts is possible owing to various factors such as variation in temperature, humidity, age of chart etc. Meridians must be perpendicular to the parallels of latitude. Dimensions of chart may be compared to the plate dimensions stated on the chart if the distortion is suspected.
7. One must try to analyse the quality of the survey. Thus on a well-surveyed chart the soundings will be closely spaced, regular with less number of blank spaces. Depth contours & shorelines must be continuous. Adequacy of topographical details is a good indication.

No chart is infallible. Every chart may have some or the other drawback. Shortcomings might be due to survey errors or subsequent alteration to seabed. A chart must never be trusted blindly. A consideration of above stated factors & effective use of echo sounder, radar & appropriate equipment must be made as frequently as may be required.





**Sextant:** *Sextant is most closely associated with the basic navigation, whether terrestrial or celestial.*
*In 1730 John Hadley an English mathematician & Thomas Godfrey an American Astronomer / Mathematician independently developed the sextant which has an arc of about one sixth of a circle, measuring angles up to one third of a circle.*
*Sir Isaac Newton in fact had invented the instrument & dispatched the details, which were never published.*

*[Pic. Instrument By 1. Godfrey (1730) 2. Newton (1700) & 3. Hadley (1730)]*

# Chapter 3: // rulers & instruments used, Measurement of Distance & Simple Plotting

### Basic Chartwork Equipment

*Q.3.1 What factors must be considered, when selecting the basic equipment for chartwork?.*

**Ans:** Neatness & clarity is the hallmark of 'quality chartwork'. A confident & well-trained navigator can be identified from the lines & drawings made by him on chart. The lines must be drawn in a manner that they appear sharp & legible. It is also important that after erasing no marks are left on chart. It means that we must use only appropriate pencil & eraser for doing chartwork. Also the compass & devider that we use must be of good quality for longer life of the chart. Following are the basic chartwork equipment:

**Eraser:** A sound quality eraser must be used on charts. There is no point using an inferior quality eraser & spoil the chart which is much more expensive. Sometimes a particular chart is frequently used. A bad eraser would spoil the paper of chart, sometimes also erasing essential navigational information.

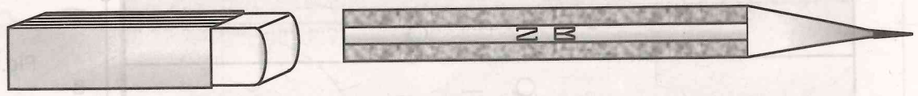



Fig. 3.1

**Pencil:** '2B' pencil is suitable for doing chartwork. Hard pencil like HB would have to be pressed hard to be legible. Also it will leave impression after it is erased. 2B pencil is soft enough for doing chartwork & draws dark & legible line even if drawn lightly. No marks are left on chart after erasing.

**Divider & Compass:** Following factors are considered when selecting a divider or a compass.

1. A long legged divider is preferred to a short-legged divider.
2. Movement of legs should not be very free. It should not be very rigid too. One should be able to adjust the divider by single hand.
3. Gradually tapering legs are preferred to sharp 'needle end legs'.

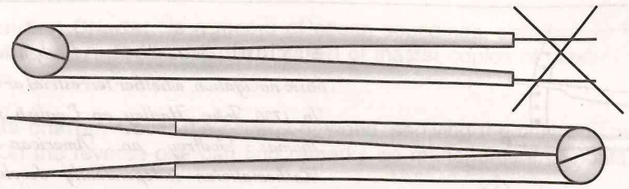


Fig. 3.2

Fig. 3.3

**Protractor:** Following factors are considered when selecting a protractor.

1. Bigger the better.
2. Transparent & of sound material.
4. Confirm the graduations for uniformity e.g. spacing may be compared with compass rose on any chart.
5. Centre-cursor is sharp & clear.

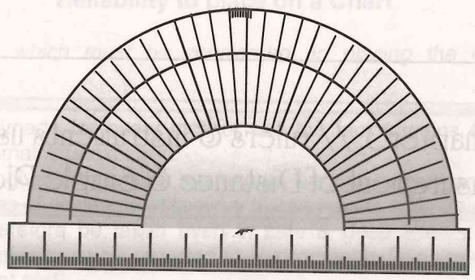


Fig. 3.4

## Parallel Ruler: choose & use, Set squares & their use on chart

*Q.3.2 (a) What factors will you take in to account in selecting a new parallel ruler?*
*(b) What is a bearing line? How is a bearing line plotted on chart?*
*(c) How will you plot a bearing line on a chart without the help of a Compass Rose?*
*(d) How will you use Setsquares to transfer a position line?*

**Hint:** (a) In selecting a new parallel ruler following factors may be considered.

1. Material should be of sound quality, scale should be transparent.
2. Area of the scale (L & B) to be adequate to ensure sufficient area of contact with chart.

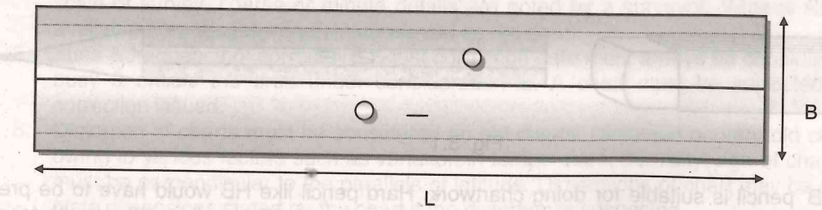



Fig.3.5

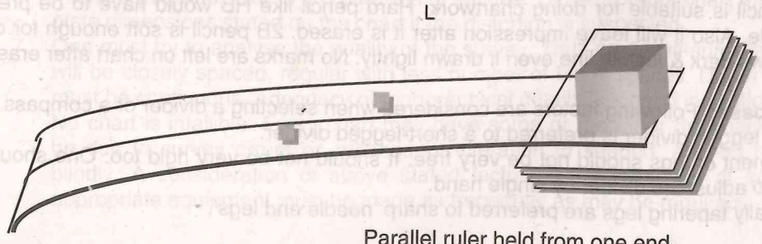


Fig. 3.6

Parallel ruler held from one end

3. No distortions, scratches etc on the scale.



4. The two parts of the scale should remain straight & together when held from one of the ends. The parallel ruler as seen in fig. 3.6 may be rejected.
5. Azimuth markings on the scale must be dark & fine. The marking must be engraved or cut in rather than embossed or just painted.
6. No play between the two parts of the scale.

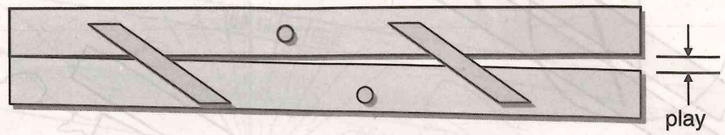



Fig. 3.7

7. It should be possible to adjust the scale to ensure the smoothness in the movement.
8. Parallel ruler should maintain the direction while it is moved through the chart. This may be checked by placing it on say, extreme western longitude of the chart & moving the ruler through the chart to extreme eastern longitude.

**(b) Bearing**

In simple terms it is an angle measured by observer at his eye or at his position between his meridian & direction in which the object lies.

or

It is a measure in degrees indicating the 'clockwise measured angle at observer's position' starting from observer's meridian ending at vertical circle through object.

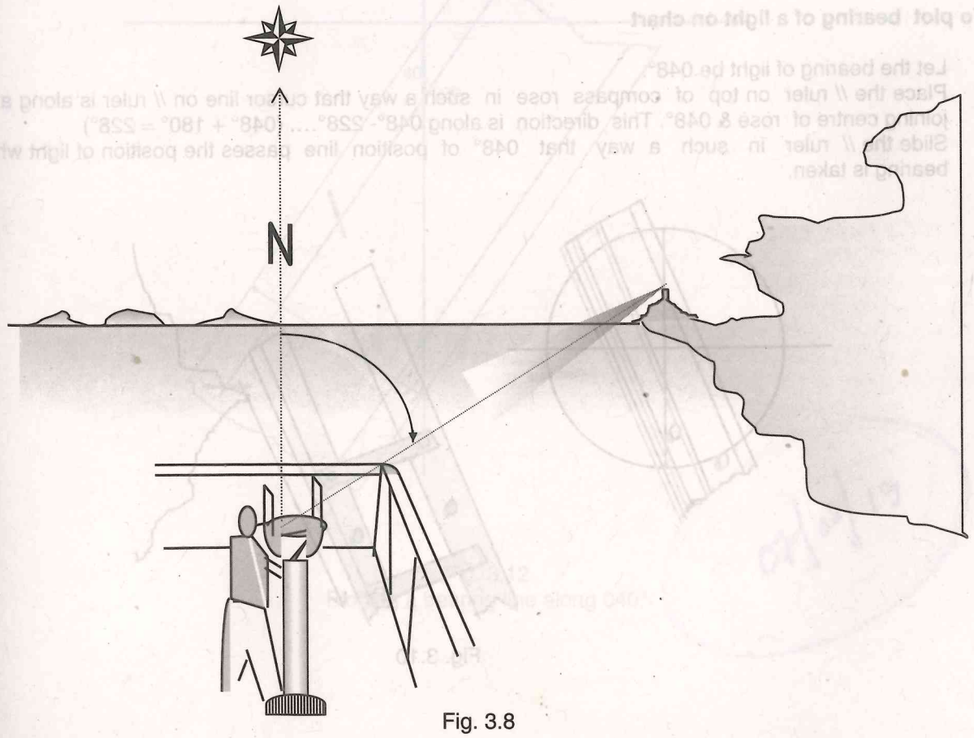



Fig. 3.8

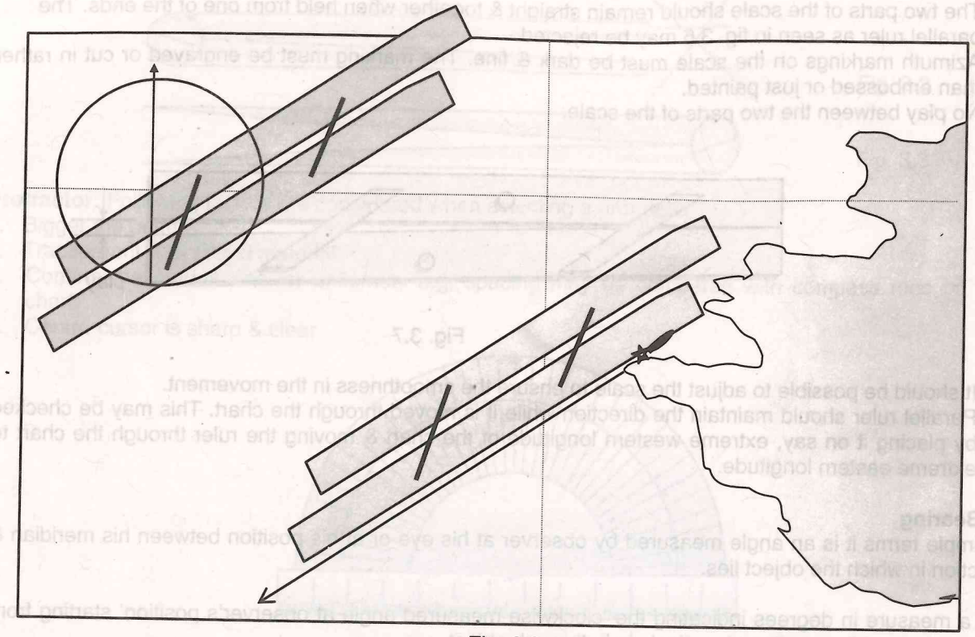


Fig. 3.9

**To plot bearing of a light on chart**

1 Let the bearing of light be 048°.
2 Place the // ruler on top of compass rose in such a way that cursor line on // ruler is along a line joining centre of rose & 048°. This direction is along 048°- 228°…. (048° + 180° = 228°)
3 Slide the // ruler in such a way that 048° of position line passes the position of light whose bearing is taken.

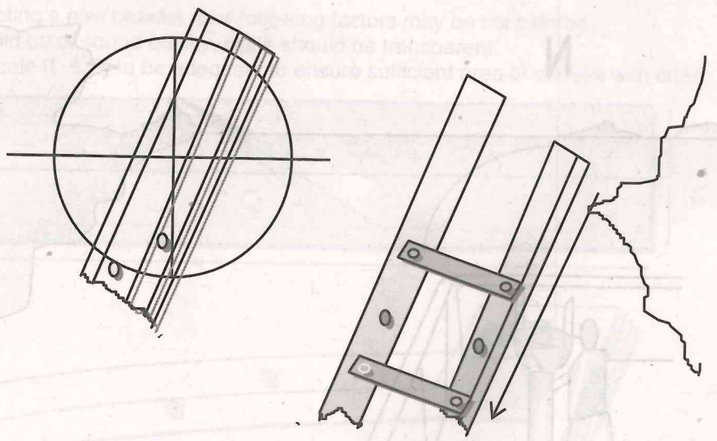


Fig. 3.10



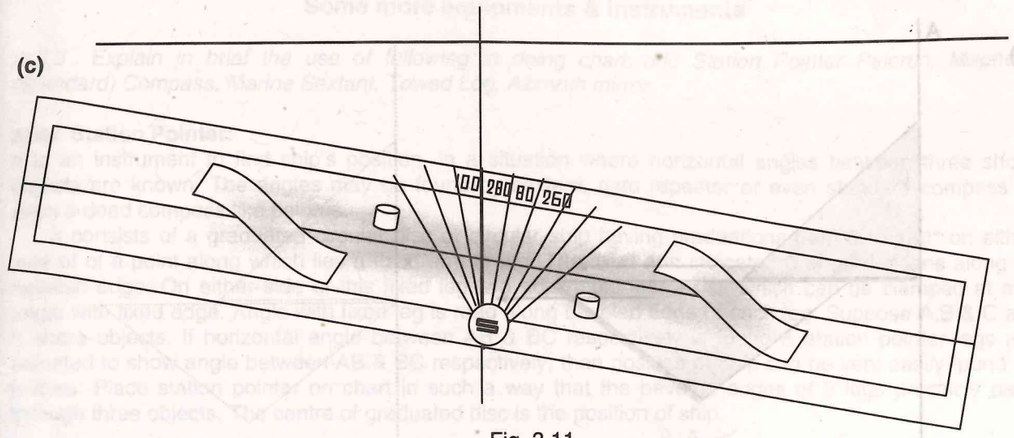



Fig. 3.11

To draw a position line along 100° - 280°,
Align 100 -280 azimuth mark & "S" mark along a meridian on the chart.

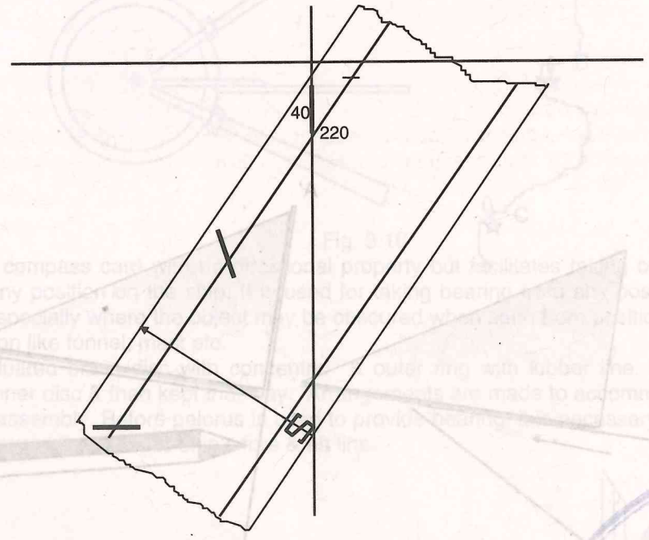



Fig. 3.12
Plotting a bearing line along 040°

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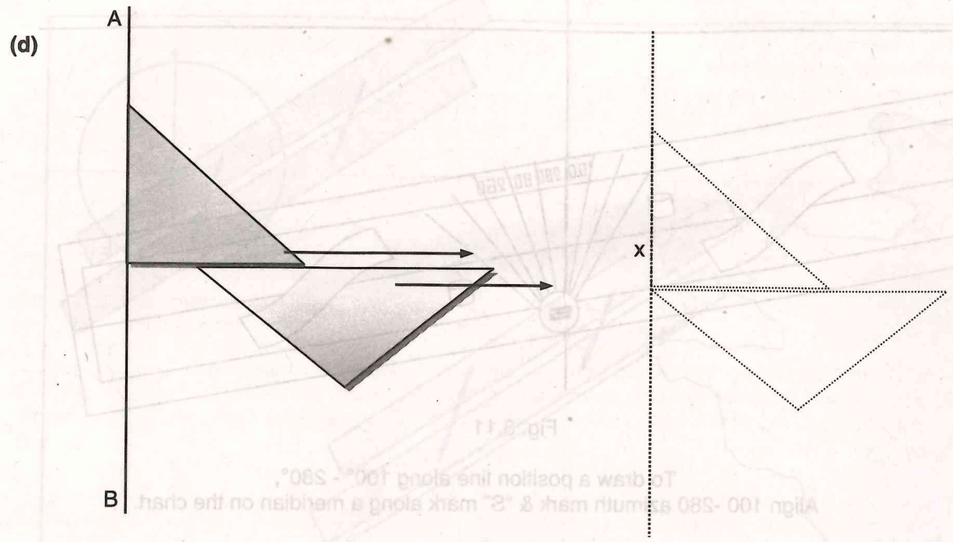



Fig. 3.13
To draw a line parallel to AB through a point 'x'

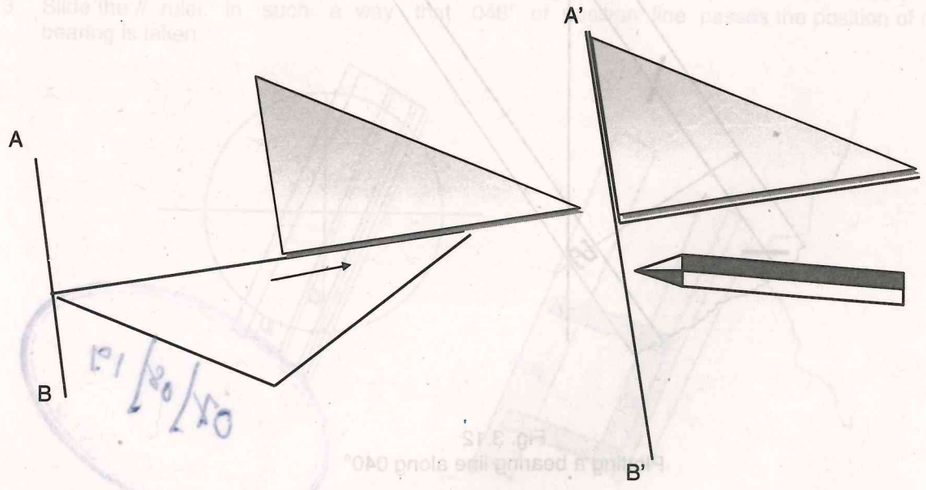



Fig. 3.14
Drawing A'B' // to AB



## Some more equipments & instruments

*Q.3.3 Explain in brief the use of following in doing chartwork: Station Pointer Pelorus, Magnetic (Standard) Compass, Marine Sextant, Towed Log, Azimuth mirror.*

**Ans: Station Pointer:**
It is an instrument to find ship's position, in a situation where horizontal angles between three shore objects are known. The angles may be found by sextant, gyro repeater or even standard compass or even a dead compass like pelorus.

It consists of a graduated circular disc or circular strip having graduations from 0 to 180° on either side of of a point along which lies a fixed arm or leg. The fixed arm indicated 0 of graduations along its beveled edge. On either side of this fixed leg two adjustable legs exist, which can be clamped at any angle with fixed edge. Angle with fixed leg is read along beveled edge of each leg. Suppose A,B & C are 3 shore objects. If horizontal angle between AB & BC respectively is found & station pointer legs are adjusted to show angle between AB & BC respectively, then position of ship can be very easily found as follows: Place station pointer on chart in such a way that the beveled edges of 3 legs precisely pass through three objects. The centre of graduated disc is the position of ship.

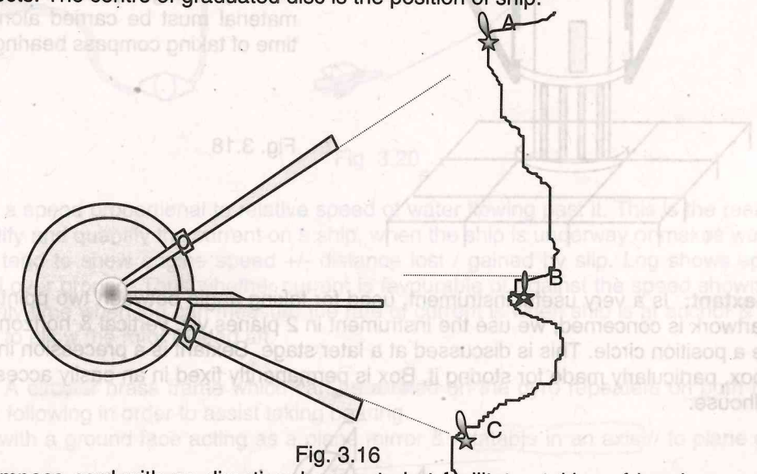



Fig. 3.16

**Pelorus:** Is a compass card with no directional property but facilitates taking of bearing or azimuth of objects, from any position on the ship. It is used for taking bearing from any position from where object can be seen, especially where the object may be obscured when seen from position of compass, due to a ship's obstruction like funnel, mast etc.

It has graduated brass disc with concentric & outer ring with lubber line. This outer ring can be rotated about inner disc & then kept that way. Arrangements are made to accommodate azimuth circle or direction vane assembly. Before pelorus is used to provide bearing, it is necessary to fix it, with its lubber line showing forward & aligned to ship's fore & aft line.

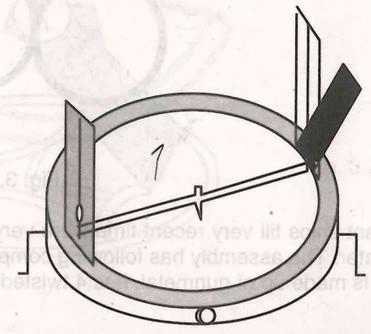
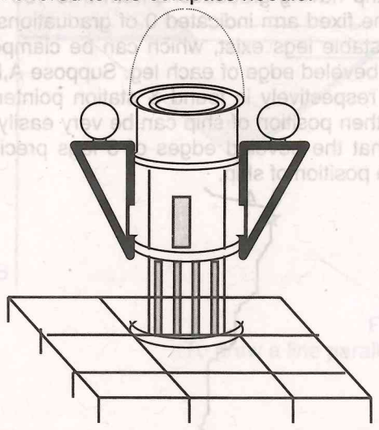


Fig. 3.17

Note: Whenever gyro fails, power to the repeaters is switched off & the repeaters on each wing are adjusted to show 0 of card at lubber mark. Now repeaters can provide relative bearings. The repeaters in a way are being used as "fixed location pelorus".

**Standard Compass:** Magnetic compass & binnacle assembly is placed on Monkey Bridge. It is placed in the centreline of ship. The compass bowl is placed with help of gimbals & pivots to ensure that compass remains horizontal. Entire assembly except the directional magnet & corrector is made up of non-magnetic material e.g. glass, wood, copper, brass etc. A compass adjuster places corrector magnets & soft iron correctors suitably. The positions of the correctors should not be altered as this will alter the correction offered to the compass needle.



With help of projector or some alternative arrangement, compass graduations are made visible in the steering position. Compass & binnacle are normally kept covered by a hood. Nearly all-round bearings can be taken from monkey bridge position. No Ferro-magnetic material must be carried along with you at the time of taking compass bearing.

Fig. 3.18

**Marine Sextant:** Is a very useful instrument, used for taking angle between two points in any plane. As far as chartwork is concerned, we use the instrument in 2 planes,viz. vertical & horizontal. It can be used to provide a position circle. This is discussed at a later stage. Sextant is a precession instrument kept in a wooden box, particularly made for storing it. Box is permanently fixed in an easily accessible place with in the wheelhouse.

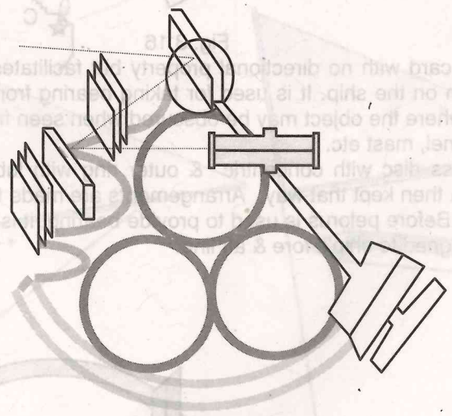


Fig. 3.19

**Towed Log:** Merchant ships till very recent time,were very commonly using the towed log for finding out ship's speed over water. The assembly has following components:

1. Rotor or Rotator: Is made up of gunmetal, has 4 twisted fins placed around a cylindrical hollow tube.



2. Line: Log line with wire core is used. The length is adjustable or preadjusted for different draft conditions. Higher speeds would need more length. Higher freeboard condition would also require more length.
3. Register: log line, which has rotor on the outboard end, is connected to Register on the inboard side, via a governor wheel.
4. Governor Wheel: Is a metal wheel with a small length of log line. End of that small line is to be secured to Register. Inboard end of streamed logline is to be attached to the centre of governor wheel. Wheel helps to arrest or absorb the undue shocks & prevents them from reaching the register.

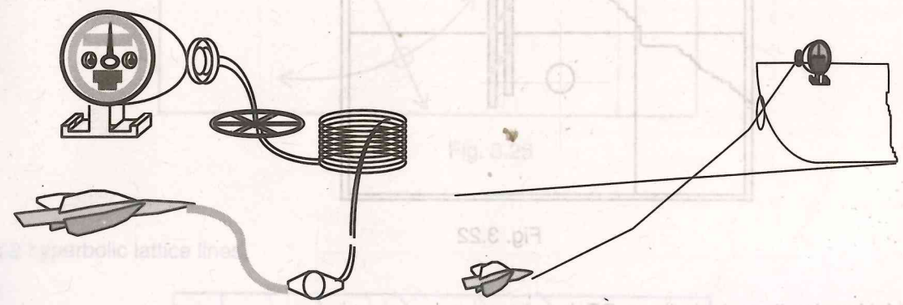


Fig. 3.20

Rotor turns at a speed proportional to relative speed of water flowing past it. This is the reason that it is not able to identify and quantify the current on a ship, when the ship is underway or makes way through water. It will only tend to show engine speed +/- distance lost / gained by slip. Log shows speed over water & not speed over ground. Thus whether current is favourable or against the speed shown by log is unaffected. The only time when log can measure the rate of current is when ship is at anchor & current is reasonably strong to allow the rotor to lead aft.

**Azimuth Mirror:** A circular brass frame which can be rotated on the gyro repeaters on both the bridge wings is fitted with following in order to assist taking bearing.

1. A glass prism with a ground face acting as a plane mirror & rotatable in an axis // to plane of circular frame.
2. A milled knob with arrow marked on side, which is used to turn the prism.
3. Shades, used when taking azimuth of sun.
4. A hollow pipe with prism on upper end & a magnifying lens within it.
5. Spirit level, to maintain azimuth circle horizontal when taking bearing or azimuth.

Terrestrial bearings are taken with milled knob showing arrow pointing down. Celestial bearings are taken with arrow pointing up. For taking celestial bearings bodies are brought down to card level & read. For taking terrestrial bearings card graduations are taken up to object level & bearing is read off.

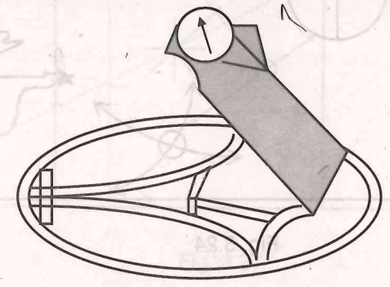


Fig. 3.21

## Plotting fixes: different ways

*Q. 3.4 What are the different types of fixes that may be plotted on a chart?*

**Hint:** Ship's position may be plotted on the chart, using a minimum of two observations or data. The set of data can be any one of the following:

(a) Latitude & Longitude.

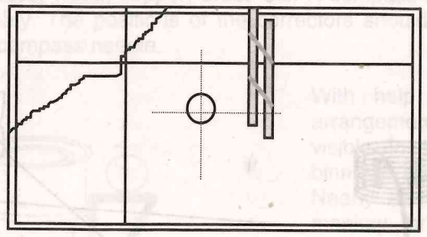


Fig. 3.22

(b) 2 terrestrial bearing lines, including a DF. bearing.

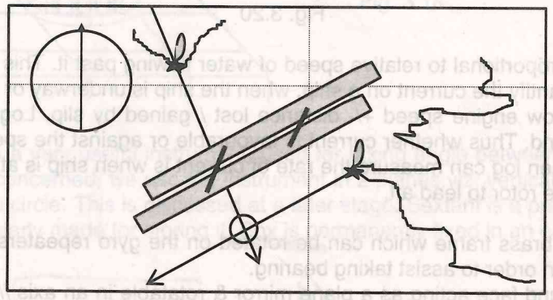


Fig. 3.23

(c) 2 position circles.

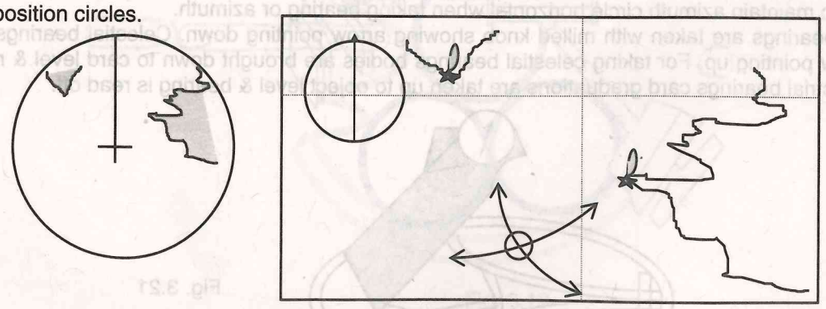


Fig. 3.24



(d) 1 bearing line & 1 position circle.

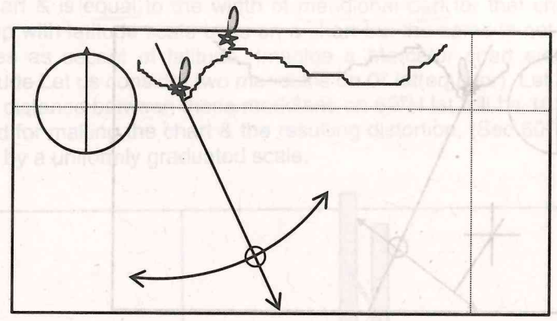


Fig. 3.25

(e) 2 hyperbolic lattice lines.

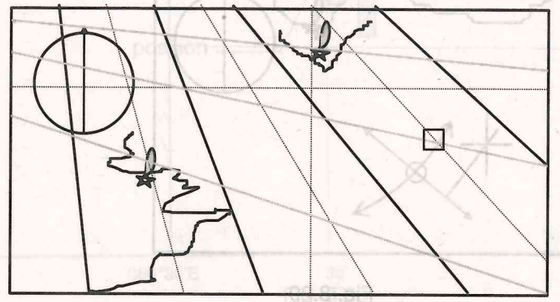


Fig. 3.26

(f) 2 celestial position lines.

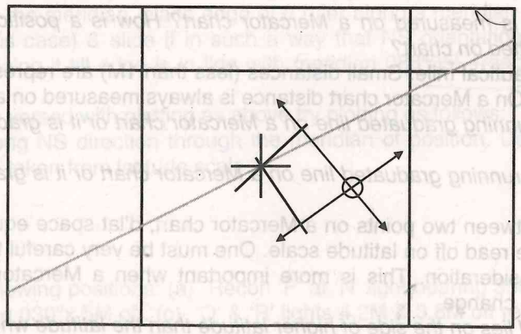


Fig. 3.27

(g) 1 celestial position line & 1 terrestrial bearing line.

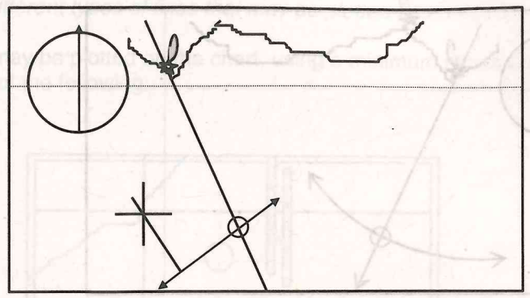


Fig. 3.28

(h) 1 celestial position line & 1 position circle.

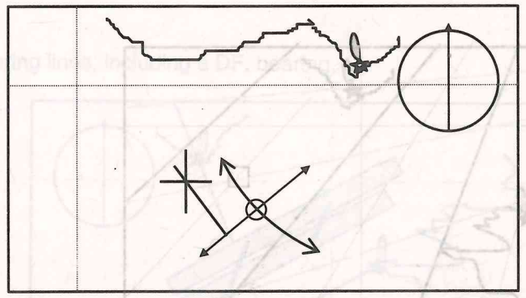


Fig. 3.29

(I) Crossing of a sounding contour simultaneous with acquiring of a position line, bearing line or a position circle.

## Measurement of distance & simple Plotting of Positions

*Q.3.5 Explain, how distance is measured on a Mercator chart? How is a position, whose latitude & longitude is known, plotted on chart?*

**Ans.** Unit of sea distances is nautical mile. Small distances (less than 1M) are represented in cables. 1M is equally divided in 10 cables. On a Mercator chart distance is always measured on a latitude scale.

*Latitude scale is the N-S running graduated line on a Mercator chart or it is graduated meridian on a Mercator chart.*

*Longitude scale is the EW running graduated line on a Mercator chart or it is graduated parallel on a Mercator chart.*

To find out the distance between two points on a Mercator chart, d'lat space equivalent to the space between the two points must be read off on latitude scale. One must be very careful to read distance only abreast of 2 points under consideration. This is more important when a Mercator chart possesses a considerable amount of latitude change.

*If latitude scale that is used lies on the side of higher latitude than the latitude where the distance is to be measured, the distance read will be less than actual distance. If latitude scale that is used lies on the side of lower latitude than the latitude where the distance is to be measured the distance read will be more than actual distance.*



Longitude scale must not be used for measuring distance. Unit of longitude scale is uniform for a given Mercator chart & is equal to the width of meridional part for that chart. Meridional part width has specific relationship with latitude scale units on a chart but the same is not uniform for different latitudes. Proportion changes as secant of latitude. Imagine a Mercator chart extending between equator & a parallel of 60° latitude.Let us consider two meridians on 0° lat(equator). Let the distance between them be 20 miles. The EW distance between these meridians on 60°N lat will be 10 miles only. This is because of the projection used for making the chart & the resulting distortion, (Sec 60° = 2). Distances on such chart cant be measured by a uniformly graduated scale.

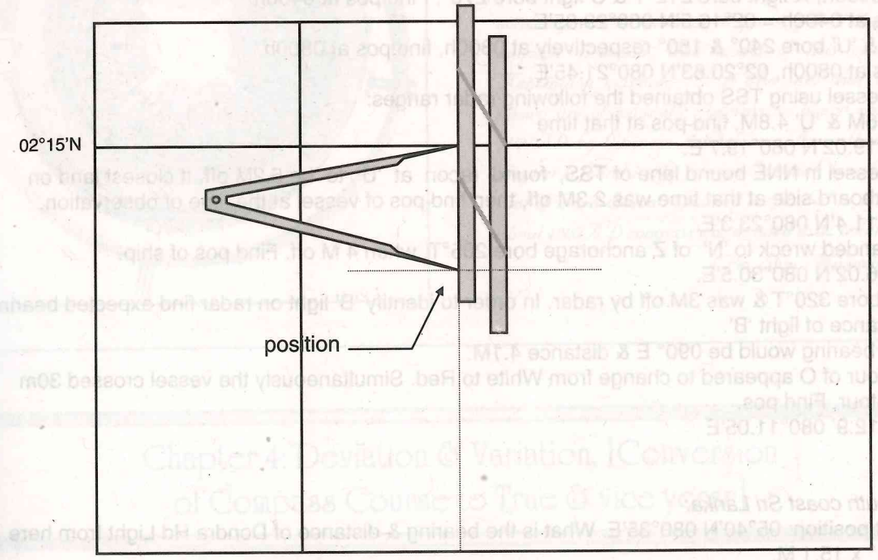



Fig. 3.30

To plot position: 02°10'N 080°35'E [Chart A to Z]

Place edge of parallel ruler along a // of latitude (in this case along 002° 15'N) & slide it in such a way that EW orientation of // ruler is maintained while sliding it. Continue doing it till edge is in line with latitude 2° 10'N (read it on latitude scale). Draw line along the edge.

Similarly to draw the meridian, place edge of // ruler along a meridian close by, (latitude scale on the Eastern border in this case) & slide it in such a way that NS orientation of // ruler is maintained while sliding it. Continue doing it till edge is in line with meridian 080°35'. (read it on longitude scale). Draw a line along the edge.

Once you re well versed with plotting as above try plotting as follows:

Place // ruler along NS direction through the meridian of position. Use divider to mark the position. Measure of divider is taken from latitude scale.

### Exercise

*Chart: Alpha to Zulu:*

Q.1 Plot & read following positions: (a) Recon 'P' at 'N' light bearing 350°T & 'Q' light bearing 080°. (b) 'O' light bearing 030°x 5M off. (c) 'Q' & 'R' lights 4.2M & 3.8M off respectively,(vessel Eastwards of these lts).

Ans: (a) 02°01.05'N 080°11.26'E (b) 02°12.2'N 080°11.7'E (c) 01°59.0'N 080°18.1'E

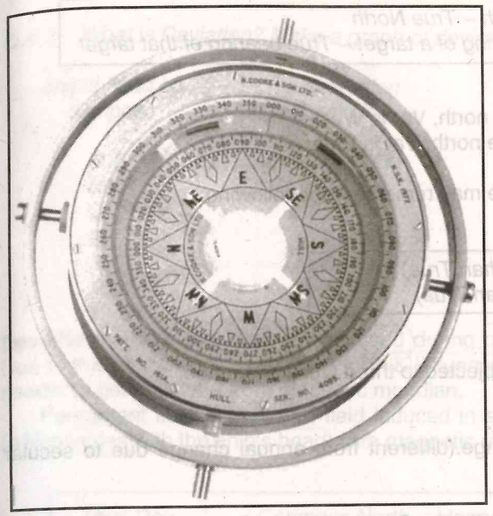
Q.1a (a) 'N' light bore 218°T x 4.8M. What is the bearing of T light from this pos? (b) 'B'light bore 049°T x 5.1M. What Co should be plotted on chart to reach pilot boarding pos off 'T' light?

Ans. 1a(a) Pos 02°06.65'N080°13.98'E Bearing of 'T' 043°T (b) 114°T.

Q.2 On what bearing, (a) does 'O' light change colour from (i) W to R or (ii) R to W?
(b) will 'N' light vessel be in transit with 'R' light?
Ans: (a) W to R on 041°T, R to W on 358°T. (b) 146.5°T - 326.5°T
Q.3 Plot position, 02°05'N 080°33'E, What is its distance from X light?
Ans: 8.7M.
Q.4 Plot a position, with Q light bearing 220° x 4.2 M. What is the distance between this position & pos B, 02°04'N 080°13'E?
Ans: 4.62M.
Q.5 At 0400h, X-light bore 212°T & U-light bore 270°. Find pos at 0400h.
Ans: Pos at 0400h = 02°16.5'N 080°29.85'E.
Q.6 'O' & 'U' bore 240° & 150° respectively at 0800h, find pos at 0800h.
Ans: Pos at 0800h, 02°20.63'N 080°21.45'E.
Q.7 A vessel using TSS obtained the following radar ranges:
'O' 6M & 'U' 4.8M, find pos at that time
Ans: 02°19.02'N 080°19.7'E.
Q.8 A vessel in NNE bound lane of TSS, found racon at 'U' to be 5.2M off. If closest land on starboard side at that time was 2.3M off, then find pos of vessel at the time of observation.
Ans: 02°11.4'N 080°23.3'E.
Q.9 Stranded wreck to 'N' of Z anchorage bore 205°T, when 4 M off. Find pos of ship.
Ans: 02°6.02'N 080°30.5'E.
Q.10 'A' bore 320°T & was 3M off by radar. In order to identify 'B' light on radar find expected bearing & distance of light 'B'.
Ans: B's bearing would be 090° E & distance 4.1M.
Q.11 Colour of O appeared to change from White to Red. Simultaneously the vessel crossed 30m contour. Find pos.
Ans: 02°12.9' 080°11.05'E

*Chart: South coast Sri Lanka:*
Q.1 Plot position: 05°40'N 080°35'E. What is the bearing & distance of Dondra Hd Light from here.
Ans: 001° x 15.1 M.
Q.2 Plot a position from where Dondra Head will bear 341° T x 9M off.
Ans: 05°46.7'N 080°38.4'E.
Q.3 Plot a position: 10M to SE of Point de Galle light. What is the bearing & distance of Dondra Head light from here?
Ans: 087°T x 15.2M.
Q.4 A vessel is 4.5M to W of Beruwala Point light house, plot a position & Co to reach 6M to SW of Colombo light. What is the Co & distance to make good?
Ans: 343°T x 25.25M.
Q.5 Dondra Head light bore 040°T & the point of land adjacent to it was 8M off from ship's pos. From this pos find the bearing & distance of Rassamunai point.
Ans: 329°T x 9.8M.
Q.6 A vessel approx to SW of Great Basses reefs found herself to lie 8.5M from G.B. reef light. Nearest land on port side was 9.5M off. Find pos of ship. Find a Co which will keep G.B. reef light at 5M to port side.
Ans: 06°03.8'N 081°24.2'E, Co 069°T.
Q.7 From a W bound ship Dondra Head point was 10.5M off & Rassamunai point was 10M off. Find pos of ship & Co to pass Point de Galle at a distance of 7M.
Ans: 05°47.5'N 080°27.5'E. Co 293°T.
Q.8 Plot the area enclosed by following coordinates:
05°30'N 080°55'E, 05°31'N 081°02'E, 05°45'N 080°52.5'E, 05°33'N 081°40.1'E.





**Compass:** *It is believed that Chinese used the magnetic compass as early as 300 BC. Where a magnetic rod was made to float in water with the half of a cork to float it. Also there was the legend of the chariot of 'Chinese emperor' whose chariot always pointed south. It was proved later that the principle of this chariot was non-magnetic & mechanical gearing held the chariot in uniform direction. The model of this chariot is in Kensington museum. It is also said that the earliest known use of magnetic compass on board ships was In 1100AD by Chinese & Italians. An instance of use of magnet is found in the famous Somnath temple where the idol of Lord Shiva remained suspended in mid air. .In about 1300A D compass was divided in 32 points.*

*[Pic. Ship's Magnetic Compass]*

# Chapter 4: Deviation & Variation, [Conversion of Compass Course to True & vice versa]

The Magnetic compass today is only back up to the gyro, but it is extremely valuable instrument owing to its reliability. Gyro is the main direction seeking instrument. Magnetic compass may not be as accurate as gyro, but it definitely is a very important direction-seeking instrument. This is because it does not require electricity to run , does not have complicated moving parts & chances of it getting spoiled are rare. It is for this reason that compass is maintained in best state of performance. The compass error is calculated every watch. It has two constituents, viz. variation & deviation. Variation was discovered long ago, the same is evident from the works & records. Deviation on the other hand was known only towards the end of the 18th century. By the beginning of 19th century, remedial action against deviation began.

## Variation

*Q.4.1 What is Variation? How do you find the variation for a place?*

**Variation:** A freely suspended magnetic needle tends to lie in a magnetic meridian. Magnetic meridian lies in a vertical plane containing a line of total force caused due to earth's magnetic poles. Earth's magnetic poles do not lie along axis of rotation like geographic poles. Magnetic poles are neither in the position of true poles nor are they diametrically opposite.
The angle between true meridian and magnetic meridian at any place is the variation for that place.
In absence of any magnetic influence other than Earth's magnetic field a magnetic needle would lie along magnetic meridian.

Thus the angle made by magnetic needle with true north under influence of ***only*** Earth's magnetic field is variation.

| | | |
|---|---|---|
| *Thus Var* | = | *Magnetic North ~ True North* |
| | = | *Magnetic bearing of a target ~ True bearing of that target* |

If magnetic needle lies to the West (left) of true north, Var is West.
If magnetic needle lies to the East (right) of true north, Var is East.

While comparing magnetic bearing with true bearing we may remember the following.

*Var W Magnetic Best (better than True)*
*Var E Magnetic Least (less than True)*

Variation is different at different places. Variation is subjected to three types of change.

1. A continuous change called Secular change.
2. A Seasonal fluctuation called annual change.(different from annual change due to secular changes).
3. A daily fluctuation called diurnal change.

Changes due to 2 or 3 may be neglected practically. Secular changes are shown on compass rose on a navigational chart

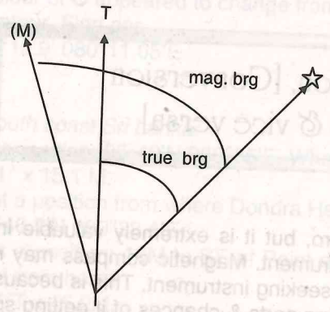



Fig. 4.1 (M) > T : Var W

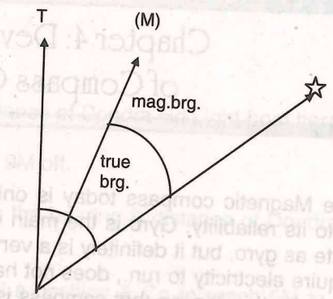



Fig. 4.2 (M) < T : Var E

Variation for any area may be found from:
(a) ***Compass rose*** of the navigational chart of the given area, or
(b) ***Admiralty Variation Chart or Isogonic Chart*** showing the lines joining areas of equal magnetic variation.

From either of the two sources mentioned above we are able to find out:

(a) Amount and sign (E or W) of variation and the year of above observation.
(b) Annual rate (amount & sign) of change of variation.

Thus **"variation 5°15' W 1978 (3'E)"** means that the variation in the area was 5°15'W for the year 1978 and the rate of annual change in variation is 3' E. i.e. the var. would be 5°12' in 1979. Variation would have been 5°18' in 1979, had the annual rate been 3'W instead of 3' E.



## *Deviation curve*

*Q.4.2 What is Deviation? Make a graph of deviation from the following Deviation readings.*

| *Ship's head by compass* | *Deviation reading* | *Ship's head by compass* | *Deviation reading* |
|---|---|---|---|
| *000°* | *2.75° W* | *180°* | *2.8° E* |
| *030°* | *2.6° W* | *210°* | *2.85° E* |
| *060°* | *2.2° W* | *240°* | *2.35° E* |
| *090°* | *1.6° W* | *270°* | *nil* |
| *120°* | *0.7° E* | *300°* | *1.8° W* |
| *150°* | *2.3° E* | *330°* | *2.4° W* |

**Deviation:** Ship's steel gets magnetised during construction & even later sometimes due to induction. Due to this magnetic lines of force form & influence magnetic needle. The influence causes the magnetic needle to get deflected from magnetic meridian.

Permanent field & Magnetic field induced in ship's body causes compass needle to be at an angle (which varies with the ship's head) with magnetic meridian. This angle is called ***deviation***.

| | | |
|---|---|---|
| *Thus Dev* | = | *Compass North ~ Magnetic North* |
| | = | *Compass bearing of a target ~Magnetic bearing of that target* |

If compass needle lies to the West (left) of magnetic north, Dev is West.
If compass needle lies to the East (right) of magnetic north Dev is East.
While comparing compass bearing with magnetic bearing we may remember the following:

*Dev W - Compass Best (better than Magnetic)*
*Dev E - Compass least (less than Magnetic)*

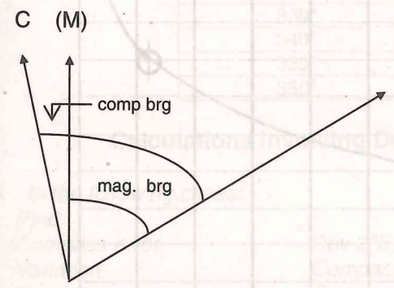



Fig. 4.3 C > (M) : Dev W

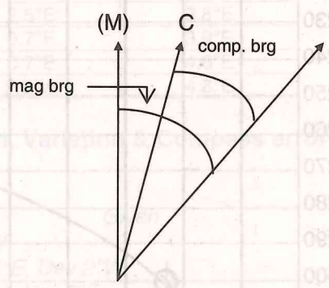



Fig. 4.4 C < (M) : Dev E

Deviation on any heading may be found by calculating ***compass error*** on that head and removing the component of variation from the error. It can also be found from the ***Deviation Card***, normally displayed in the chart room.

It would be most desirable that deviation is as low as possible in all the headings & does not fluctuate unduly as ship's Co is altered. For this ship's compass is adjusted by introducing correctors & magnets to counteract disturbing forces. This is done by a compass adjuster. Arrangement must not be disturbed once adjustments are over. A deviation card is made showing deviation on different compass headings.

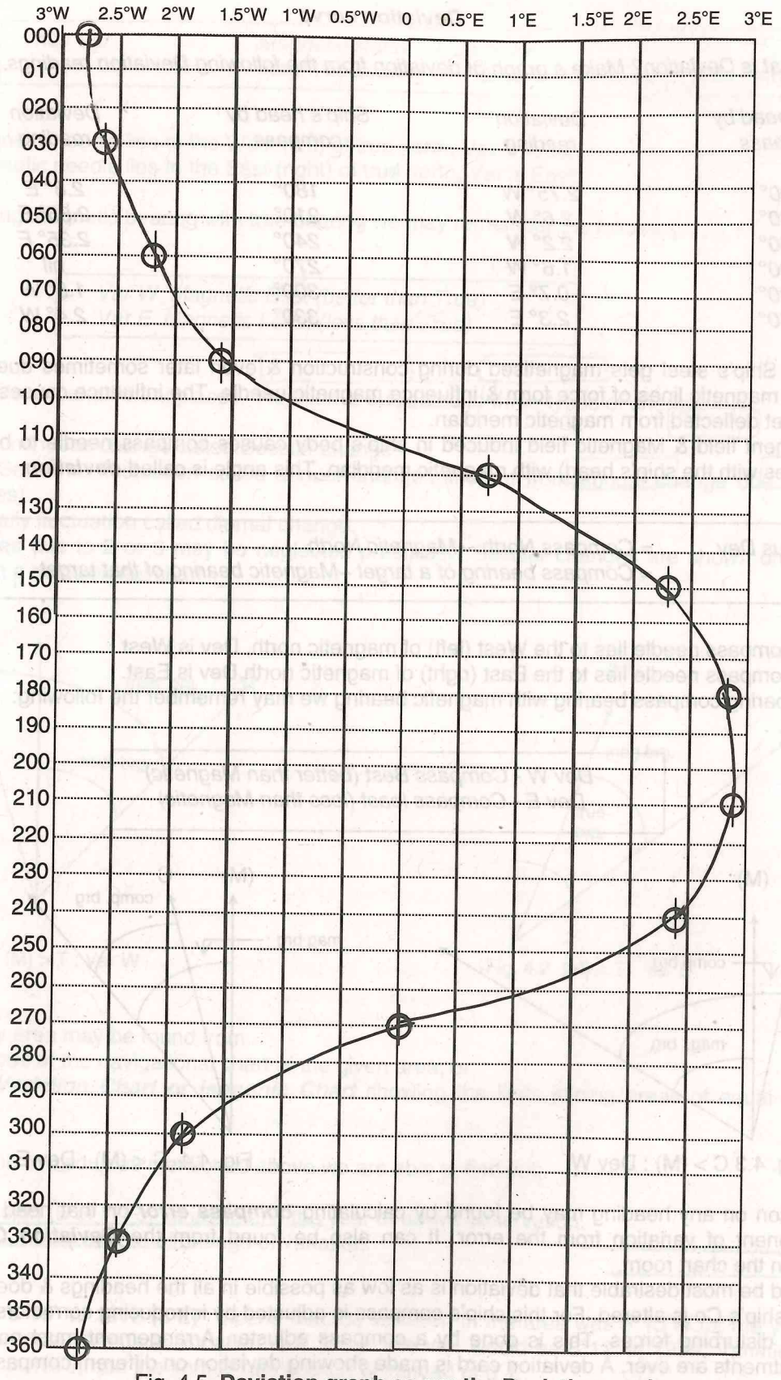



Fig. 4.5 **Deviation graph as per the Deviation card.**



## DEVIATION CARD

| Head by Compass | M.V. Jala Ganga | M.V. Jal Vallabh |
|---|---|---|
| 000° | 2.0°W | 4.8°E |
| 010° | 3.6°W | 4.4°E |
| 020° | 5.8°W | 4.4°E |
| 030° | 7.4°W | 3.9°E |
| 040° | 8.8°W | 3.4°E |
| 050° | 10.4°W | 2.8°E |
| 060° | 11.3°W | 1.6°E |
| 070° | 12.3°W | 0.6°E |
| 080° | 12.8°W | 0.6°W |
| 090° | 12.6°W | 1.8°W |
| 100° | 11.0°W | 2.3°W |
| 110° | 10.8°W | 2.9°W |
| 120° | 8.9°W | 3.4°W |
| 130° | 6.9°W | 3.9°W |
| 140° | 5.0°W | 5.1°W |
| 150° | 3.0°W | 5.4°W |
| 160° | 1.4°W | 5.6°W |
| 170° | 0.7°E | 5.6°W |
| 180° | 2.4°E | 5.5°W |
| 190° | 3.6°E | 5.4°W |
| 200° | 5.4°E | 4.8°W |
| 210° | 6.5°E | 4.0°W |
| 220° | 8.3°E | 3.7°W |
| 230° | 9.8°E | 3.4°W |
| 240° | 11.0°E | 2.4°W |
| 250° | 12.2°E | 2.5°W |
| 260° | 12.7°E | 1.9°W |
| 270° | 12.5°E | 1.2°W |
| 280° | 11.5°E | 0.4°W |
| 290° | 9.8°E | 0.6°W |
| 300° | 8.2°E | 1.3°E |
| 310° | 6.5°E | 2.1°E |
| 320° | 4.7°E | 2.8°E |
| 330° | 2.5°E | 3.8°E |
| 340° | 0.7°E | 3.9°E |
| 350° | 0.7°E | 4.6°E |
| 360° | 2.0°W | 4.8°E |

### Calculations involving Deviation, Variation & Compass error

*Q. 4.3 In the following cases:*

| | *Find* | *Given* |
|---|---|---|
| *1* | *Compass error* | *Dev 2°E, Var 3°W* |
| *2* | *Variation* | *Compass error 4°E, Dev 2°W* |
| *3* | *Deviation* | *Compass error nil, Var 2°E* |
| *4* | *True course* | *Compass course 150°C, Var 2°E, Dev for 150°C = 2.7°E* |
| *5* | *Compass course* | *True course 170°, Var 2°W Dev on 161° = 5.1°E, on 166.5° = 5.3°E & on 172° = 5.5°E* |
| *6* | *Compass course* | *True course 010°, Var 1°W Dev on 11° = 5.5°W, on 16.5° = 5.3°W & on 22° = 5.1°W* |

**Hint:** Variation & Deviation may be added together if of same name & if the two are of different name then the smaller one is subtracted from bigger. In either case the resultant compass error gets the name of the bigger component.

Thus:

(1) Compass error = 1° W.
(2) Variation = 6° E.
(3) Deviation = 2° W.

(4) Deviation = 2.7° E
Var = 2° E
Hence total error = 4.7° E
Compass course = 150° C
True course = 154.7° T (error E compass least).

(5) True course = 170° T
Var = 2° W
Mag.course = 172° (M) (Mag. best)

Compass course must be such that compass course +/- Dev = 172°. Thus found by trial & error method as follows:
We may assume that Mag. course = Compass course, (approximately) = 172°, for which Dev = 5.5°E.
Hence approx. compass error = 5.5°E - 2°W = 3.5°E.
∴ approx. compass Co = 166.5°.
Dev for 166.5°C = 5.3°E, giving compass error = 5.3 - 2 = 3.3°E.
∴ required compass Co = 166.7°.
Calculations may be shown as follows :

| | | |
|---|---|---|
| True | = | 170° |
| Var | = | 2°W |
| Mag | = | 172°(m) |
| Approx. Dev. | = | 5.5°E |
| Approx Comp. | = | 166.5° |
| Deviation for 166.5° | = | 5.3°E |
| Comp = 172° - 5.3° = 166.7° | | |

(6) Co = 011°(M), Dev for 11°(M) = 5.5°W.
Approx compass Co = 16.5°C. Dev for 16.5°C = 5.3°W.
Tot. error = 6.3°W.
∴ required compass Co = 16.3°.
or

| | |
|---|---|
| True Co | = 010° |
| Var | = 1°W |
| Mag | = 011°(m) |
| Approx Dev | =5.5° W |
| Approx Comp | = 016.5° |
| Dev | = 5.3° W |
| Comp | = 11° + 5.3° |
| | = 16.3° C |

## Calculations involving True / Relative bearing & Compass Error

*Q. 4.4*

| | *Given* | *Find* |
|---|---|---|
| 1. | *Compass brg of a target 205° C, C.Error 2° W* | *True bearing* |
| 2. | *Compass course 310° C, Compass brg 017°C, Variation nil. Dev on 310°C = 0.6°E* | *Relative & True brg.* |
| 3. | *Compass head 007° C, Relative brg 81.3° (starboard), Variation 3° W. Dev 5.3° W.* | *Compass & True brg.* |
| 4. | *Gyro head 126°G, Compass head 127°C, Variation 1.5° W, Gyro brg of Light house 221°G, Dev on head = 0.7°E* | *Relative, Compass, & True brg of Light house.* |



**Hint:**
(1) **True brg** = 205 - 2 = **203°.** (Error W Compass best)
(2) **Relative brg** = 310° ~ 017° **= 67° (starboard)**
Dev = 0.6° E
C.Error = 0.6° E
**True brg = 017.6° T**

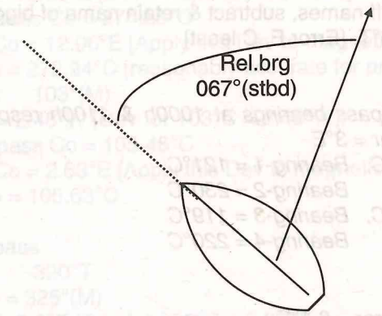


Fig. 4.6



(3) Compass brg = 7 + 81.3 = 88.3° C
C.Error = 8.3° W
**True brg = 080° T.**

(4) **Relative brg** = 221° ~ 126° **= 95° (Stbd)**
Compass head = 127° C &
Compass error = 0.8° W
Hence True heading = 126.2° T
Also Gyro error = 0.2° Low
**True brg = 221.2° T**
**Compass brg 222° C**

## Conversion of courses

*Q.4.5 Following courses on magnetic compass were steered by M.V. JalaGanga in an area where variation is 2°W. Write down the true course steered.*
*1. 047° 2. 113° 3. 275° 4. 294°*

**Sol. 1** Compass heading = 047°C
Dev for 40°C = 8.8°W & that for 50°C = 10.4°W.
Hence Deviation for 47°C = 9.92°W.
Var = 2°W
Compass error = 9.92 + 2 = 11.92°W [Dev,Var same name, add]
& True course = 047° - 11.92°W= 35.08°T. [Error W, C best]

**2** Compass heading = 113°C
Dev for 110°C = 10.8°W & that for 120°C = 8.9°W.
Hence Deviation for 113°C = 10.23°W.
Var = 2°W
Compass error = 10.23 + 2 = 12.23°W [Dev, Var same name, add]
& True course = 113° - 12.23°W= 100.77°T. [Error W, C best

**3** Compass heading = 275°C

Deviation for 275°C = 12°E
Var = 2°W
Compass error = 12 - 2 = 10°E [Dev, Var diff names, subtract & retain name of bigger]
True course = 275° + 10°E= 285°T. [Error E, C least].

4 Compass heading = 294°C
Deviation for 275°C = 9.16°E
Var = 2°W
Compass error = 7.16°E [Dev, Var diff names, subtract & retain name of bigger]
True course = 294° + 7.16°E= 301.16°T. [Error E, C least]

*Q4.6. M.V. Jal Vallabh took following compass bearings at 1000h & 1100h respectively. Write down true bearings to be plotted on chart. Given Var = 3°E*

*At 1000h: Compass head 045°C, Bearing-1 = 121°C*
*Bearing-2 = 230°C*
*At 1100h: Compass head 123°C, Bearing-3 = 119°C*
*Bearing-4 = 220°C*

**Sol.** At 1000h compass head = 045°C
Dev = 3.1°E & Var = 3°E ∴Compass error = 6.1°E.
True bearing-1 = 121 + 6.1 = 127.1°T.
True bearing-2 = 230 + 6.1 = 236.1°T.
At 1100h compass head = 123°C
Dev = 3.55°W & Var = 3°E ∴Compass error = 0.55°W.
True bearing-3 = 118.45°T.
True bearing-4 = 219.45°T.

*Q.4.7 Convert the following courses:*

| | | |
|---|---|---|
| *1. Compass to magnetic* | *Jala Ganga* | *124°C & 317°C* |
| | *Jal Vallabh* | *150°C & 325°C* |
| *2. True to magnetic* | *Jala Ganga* | *125°T & 116°T* |
| *(Var = 7°E)* | *Jal Vallabh* | *221°T & 196°T* |
| *3. Magnetic to true* | *Jala Ganga* | *118°(M)* |
| *(Var = 4°W)* | *Jal Vallabh* | *110°(M)* |
| *4. Magnetic to compass* | *Jala Ganga* | *285°(M)* |
| | *Jal Vallabh* | *103°(M)* |
| *5. True to compass* | *Jal Vallabh* | *320°T* |
| *(Var = 5°W)* | | |

**Sol** 1. Compass to magnetic
Jala Ganga 124°C & 317°C
Dev = 8.1°W & 5.24° respectively.
Magnetic Co = 115.9°(M) & 322.24(M) respectively

Jal Vallabh 150°C & 325°C
Dev = 5.4°W & 3.3°E respectively.
Magnetic Co = 144.6°(M) & 328.3°(M) respectively.

2. True to magnetic
[Var E, compass side least. Var W, compass side best]
Jala Ganga 125°T & 116°T
Var = 7°E. Magnetic Co = 118°M & 109°M respectively.

Jal Vallabh 221°T & 196°T
Magnetic Co = 214°M & 189°M respectively.



3. Magnetic to true
[Var E, compass side least. Var W, compass side best]
Jala Ganga 114°T
Jal Vallabh 106°T

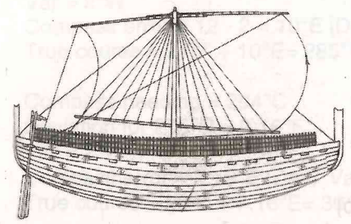
4. Magnetic to compass
Jala Ganga 285°(M)
Approx Dev = 10.65°E [Dev for 285°C = 10.65°E]
Approx Compass Co = 274.35°C
Dev for this Co = 12.06°E [Apply this Dev to magnetic Co]
Compass Co = 272.94°C [reasonably accurate for practical purposes]
Jal Vallabh 103°(M)
Approx Dev = 2.48°W [Dev for 103°C = 2.48°W]
Approx Compass Co = 105.48°C
Dev for this Co = 2.63°E [Apply this Dev to magnetic Co]
Compass Co = 105.63°C

5. True to compass
Jal Vallabh 320°T
Magnetic Co = 325°(M)
Approx Dev = 3.3°E [Dev for 325°C = 3.3°E]
Approx Compass Co = 321.7°C
Dev for this Co = 2.97°E
Total error = 5°W + 2.97°E = 2.03W. [Apply this to True Co]
Compass Co = 322.03°C.

**Exercise:**

Q.1 On a Co of 110°T, colour of 'O' changed from Red to White. Compass bearing of 'O' at that time was 005°. If variation in the area is 2°W, find dev of compass on above heading.

Ans. True bearing of 'O' = 357.5°, Compass error = 7.5°W. Dev = 5.5°W.



**Phoenician & Greek Ships:** *Phoenicians were leading seafarers of Mediterranean during 1200BC They lived along Eastern Shore of Mediterranean. The ships were of big size. Later the double mast ships were developed. The best of ancient war ship designs were developed by Greeks.*

*[Pic. Phoenecian Cargo Ship (1400BC)]*

# Chapter 5: A Few Terms Associated With Chartwork, Symbols & Abbreviations

One of the aims of a navigational chart is to clearly indicate the position & caution against presence of underwater obstructions, rocks, wrecks & other dangers to navigation. One should be able to identify these dangers marked on chart. On other hand he also should be able to identify & use the navigational aids or structures present in an area. In this chapter we will deal with different features commonly appearing on a navigational chart.

*Chart 5011 (INT)* is a booklet published by hydrographic department of United Kingdom. It contains symbols & Abbreviation used on Admiralty charts. This edition is based on the "chart specification of the IHO (International Hydrographic Organization) adopted in 1982.

The symbols/Abbreviation are listed under various headings viz. Topography, Hydrography, Aids & Service

*Topography*: This section covers natural & cultural features, landmarks ports & topographic terms.

*Hydrography*: This section is very important. It covers symbols used for Rocks, wrecks, obstructions off shore installations & depths. Above data is extremely essential for safety of navigation. In addition the symbols used for Tides, currents, routing, Limits are covered

Heights stated on a BA chart are indicated above a height datum, which is usually the MHWS, normally one of the highest levels of water, in an area. Thus height of a light, height of peak of a mountain, overhead clearance of bridge, cable etc. are measured & indicated above MHWS. Even the coastline is drawn for MHWS level.

All depths on the other hand are referred to CD, which normally on a BA chart is lowest astronomical tide for that area. Thus if water level falls to the level of chart datum, one would actually measure the sounding of water in an area equal to that indicated on chart.

A rock may be always visible above water level, occassionaly visible or remain underwater. Accordingly a rock may be represented as on chart as isolated rock, underwater rock, drying rock etc.

*Representing an 'isolated rock', an 'underwater rock' & a 'drying rock' on a chart.*

(1) Rock which does not cover at any tidal level. i.e. protrudes above MHWS. if the height above height datum is 3.2m then it may be indicated as follows:

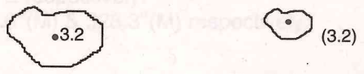



Fig. 5.1

(2) A rock higher than depth datum & lower than height datum will be seen, sometimes only when the tide has fallen to such a level that the level is below the peak of the rock. In other words, when height of tide less than as indicated in (2), the rock is visible. If height of tide is more then the rock is submerged. Such a height is called drying height & indicated as follows.



Thus a figure in bracket & also underlined indicates the distance of such peak above chart datum.

*(1₂) or (2₂)

Fig. 5.3

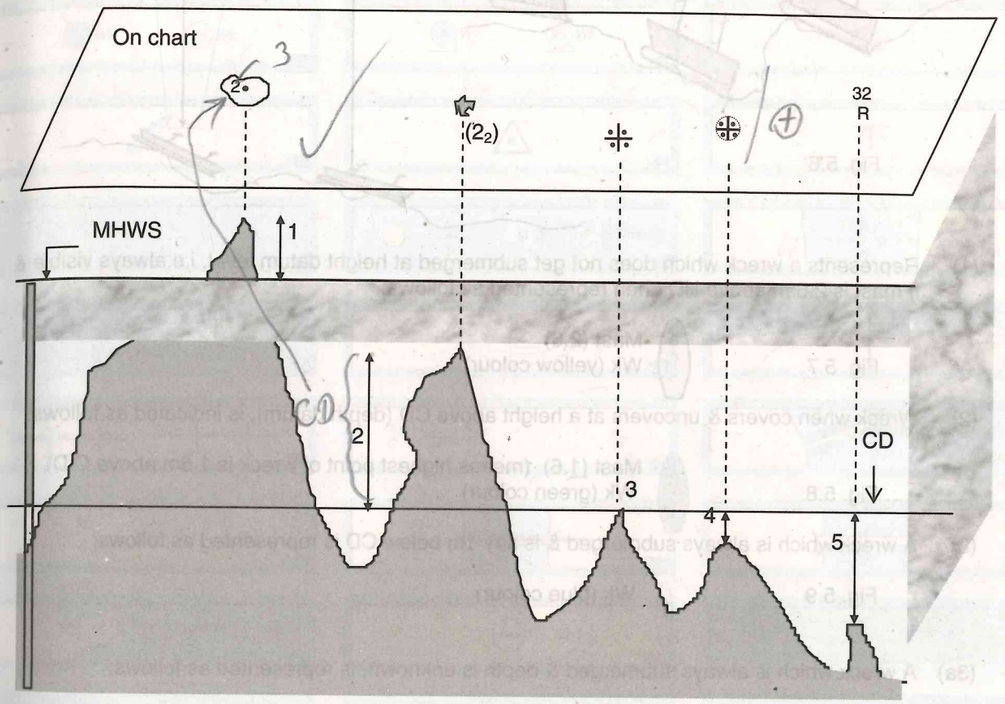



Fig. 5.2

(3) A rock which is just at the surface of water at CD or is just visible when level drops to CD is represented as follows: The symbol indicates, rock awash at C.D.

Fig. 5.4

(4) If rock is always going to be submerged underwater & depth of same is unknown, but considered dangerous for surface navigation is represented as follows:

Fig 5.5

(4a) A rock whose peak is say 8m below CD level is represented as follows:
+(8), when it lies within 10m or corresponding depth contour & is represented as ⊕ (8), if it lies outside 10m contour, say in between 10 & 20m depth contours.

(5) Underwater rock not dangerous to surface navigation is represented as follows:

32
R

A wreck is represented on a chart by different symbols depending on whether it is visible or not, depth, scale of chart etc.

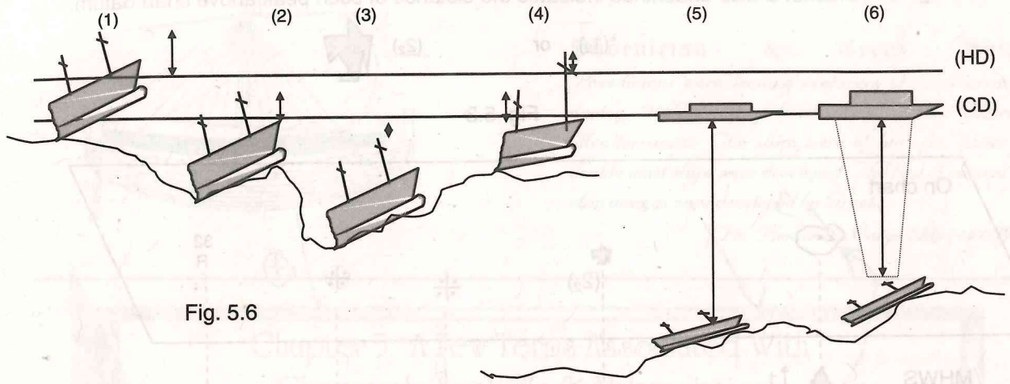



Fig. 5.6

(1) Represents a wreck which does not get submerged at height datum level, i.e.always visible & if mast is 2.6 m above HD, then represented as follows:

Fig. 5.7  Mast (2.6)
Wk (yellow colour)

(2) Wreck when covers & uncovers at a height above CD (depth datum), is indicated as follows:

Fig. 5.8  Mast (1.6) (means highest point of wreck is 1.6m above C.D)
Wk (green colour)

(3) A wreck which is always submerged & is say 1m below CD is represented as follows:

Fig. 5.9  Wk (blue colour)

(3a) A wreck which is always submerged & depth is unknown, is represented as follows:

Fig. 5.10  Wk (blue colour)

(4) Wreck of which only masts are visible at CD is represented as follows:

Fig. 5.11  Mast ($1_4$) one of the masts is 1.4m above HD
Mast ($1_1$) other mast is 1.1 m above CD

(5) If depth over wreck is obtained by soundings but not by wire sweep, it is represented as follows: (depth below CD)

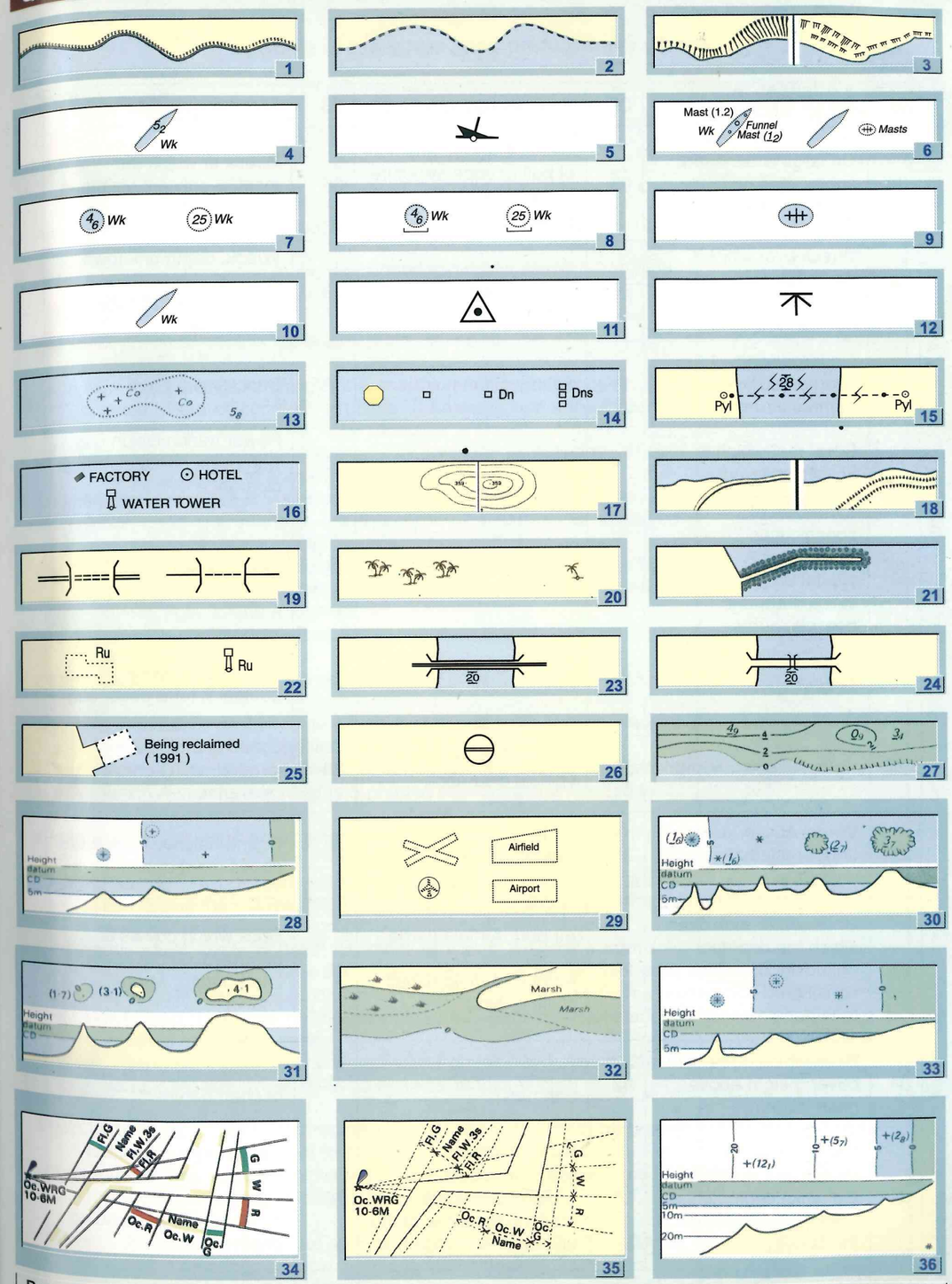
Fig. 5.12 (36) Wk , (20) Wk etc.

(6) If the depth is found by wire sweep then the depth is marked as follows: (depth below CD)

Fig. 5.13 (36) Wk , (20) Wk etc.

# Symbols used on BA Charts

**Q.5.1 What do the following Symbols indicate on BA Charts ?**



**Ans:**

| | | | | | |
|---|---|---|---|---|---|
| 01 | Sandy shore | 02 | Coastline un-surveyed | 03 | Steep coast, cliffs |
| 04 | On large scale chart, submerged wreck, depth known | 05 | Wreck showing any part of hull or superstructure at the level of chart datum | 06 | Wreck of which the mast(s) only are visible at chart datum |
| 07 | Wreck over which depth has been obtained by sounding but not wire sweep | 08 | Wreck which has been swept by wire to the depth shown | 09 | Wreck, depth unknown, which is considered dangerous to surface navigation |
| 10 | On large scale chart, submerged wreck depth unknown | 11 | Triangulation point | 12 | Bench mark |
| 13 | Coral reef which is always covered | 14 | Dolphin | 15 | Power transmission line with pylons & safe vertical clearance |
| 16 | Examples of conspicuous landmarks. A legend in capital letters indicates that a feature is conspicuous | 17 | Form lines with spot height | 18 | Dyke, Levee |
| 19 | Tunnel | 20 | Palm | 21 | Breakwater (loose boulders, tetra pods, etc) |
| 22 | Ruin, Ruined landmark | 23 | Fixed bridge with vertical clearance | 24 | Opening bridge (in general) with vertical clearance |
| 25 | Works at sea, Area under reclamation, with year date | 26 | Custom office | 27 | Drying heights & contours above chart datum |
| 28 | Underwater rock over which the depth is unknown, but which is considered dangerous to surface navigation | 29 | Air port, Airfield (large scale)<br>Air port, Airfield (small scale charts) | 30 | Rock which covers & uncovers, height above chart datum, where known |
| 31 | Rock which does not cover, height above chart datum | 32 | Marsh, Swamp, Saltmarsh | 33 | Rock awash at the level of chart datum |
| 34 | Sector lights on multicoloured charts, the white sector limits marking the sides of the fairway | 35 | Sector lights on standard charts, the white sector limits marking the sides of the fairway | 36 | Dangerous underwater rock of known depth<br><br>Inside the corresponding depth area |



## Some of the terms used on Admiralty Charts

***Term*** — ***Definition*** — ***In this coloumn student can make symbol or state the abbreviation abreast of def$^n$ (where applicable).***

*Awash:* A shoal, rock etc. is called awash if its upper portion is within 10cm of water level

*Bar:* Causes obstruction to the entry of a ship & owing to reduced depth at the entry to a river or port approach caused by sand, silt, mud etc.

*Bathymetry:* The science of measurement of marine depths.

*Beacon:* A fixed & artificial navigational mark, normally erected over water using pillars or concrete structure. It has a typical construction & may be fitted with light & radar reflector.

*Benchmark:* Some fixed marking made in concrete or masonry, whose height is related to some known datum.

*Boulder:* Water rounded stones more than 256mm in size.

*Breakwater:* Solid wall made to the seawards of a harbour or sheltered anchorage to break force of sea waves.

*Buoy:* Floating, moored artificial mark erected for different purposes such as marking channel, danger etc.. It is identified by characteristic colour, light, shape & topmark.

*Caisson:* Structures used to close the entrance to drydocks, locks & non tidal basins.

*Cape:* Land in comparison with adjacent coast projects in to open sea.

*Channel:* Special navigable route which is dredged or is naturally useful route, running through river, straits, harbours etc.

*Chart datum:* Is normally the lowest astronomical tide, and is the level to which Admiralty tide heights & charted soundings are referred to.

*Clearing Bearings:* Indicate whether a ship is clear or not of a danger.

*Clearing Marks:* Two or more marks are positioned in such a way that a line joining them is clearing bearing or a bearing separating danger area from safe area.

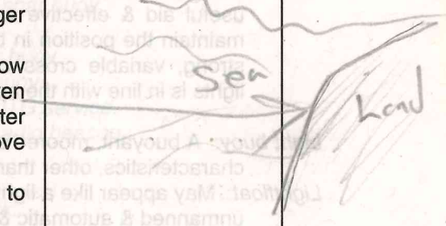
*Continental shelf:* Upto a depth of 200m of water, extending from low water line of land, (some times only upto 100m & some times even upto 350m depth), the change of depth is very gradual, thereafter the slope is very steep. The area of gradual slope described above is called continental shelf.

*Current:* Generally upper layers of sea water develop movement due to various reasons which must be non tidal in their origin

*Deep water route:* On a chart sometimes a route is indicated by dotted line & is kept maintained for the depth indicated.

*Degaussing Range:* Is area normally marked by buoys, where sensors are placed on seabed to measure ship's magnetic fields.

*Dolphin:* A wooden or concrete structure made on shore or in water to assist in moorings or allow moorings on themselves.



*Drying Height:* Is a sounding figure which is underlined unlike normal sounding figures, indicating height above CD or a tidal height at which the rock in question uncovers or is just visible or is awash .

*Ebbing:* Going out of a tidal stream from a port on a falling tide.

*Eddy:* A tidal stream is normally modified in direction & strength due to the curved & varying shapes provided by land or shore, giving rise to circular movement or movement different from neighbouring streams, called eddy.

*Fish stakes:* Row of stakes, extending from shore even upto navigable depths, ending in a structure which allows for lowering nets.

*Foreshore:* Part of shore lying between MHWS & MLWS.

*Foul Area:* Because of obstructions, small wrecks etc. on seabed, area is not suitable for anchoring, although it may not be dangerous for surface navigation.

*Flooding:* Coming in a port or harbour of tidal stream on a rising tide.

*Gravel:* Water worn round stones, upto a diameter of about 12mm including coarse sand.

*Gulf:* Geographically similar to bay i.e. sea area enclosed partly by land but of much larger in size.

*Hydrography:* Is art of surveying & recording of measurements obtained in sea & connected navigable waters, including adjacent lands & additional data required for safe navigation.

*Inshore Traffic Zone:* Area lying between landward boundary of TSS & adjacent coast, is sometimes designated as ITZ, in accordance with the collision regulations,1972.

*Jetty:* A structure normally made perpendicular to the coast, strong enough & of size to allow berthing of ships alongside.

*LANBY:* Is large automatic navigational buoy, large in size & weight. It may weigh upto 140 tonnes & be of a height upto 12m.

*Leading lights & leading line:* Leading lights include a main light & a minor light of a lower elevation & to the seawards of main light, placed along a direction which helps to take transit bearing. It is a very useful aid & effective way of guiding the ships to help them to maintain the position in the middle of a channel. Particularly so in strong, variable cross currents. Leading line provided by these lights is in line with the approach channel.

*Light buoy:* A buoyant, moored structure of particular colour, shape & light characteristics, other than LANBY.

*Lightfloat:* May appear like a lightvessel with many aids to navigation but is unmanned & automatic & may be placed in strong current or traffic areas .

*Light vessel or Lightship:* Manned vessel with light of high intensity & other aids to navigation.

*Magnetic anomaly:* Effect causing distortion in normal magnetic lines of force, in certain areas, causing a change in variation, dip etc. & thus causing wandering of magnetic compass.

*Patent slip:* Rails are laid perpendicular to coast between levels of MHWS & MLWS, made to facilitates bottom cleaning of small ships, which can be carried uprails by a cradle.



*Quay:* Structure made normally // to coast or within a port, strong & big enough to allow berthing of ships for working of cargo.

*Recommended route:* A route marked on chart for navigation in critical or traffic areas normally marked by centreline buoys.

*Reefs:* Low rocky or coral area, generally flat, partly above water & is dangerous for navigation.

*Roads:* Open anchorage normally without natural protection & is on outside of a harbour, is also called outer anchorage, loosely.

*Seamount:* An isolated, conical, underwater projection of seabed.

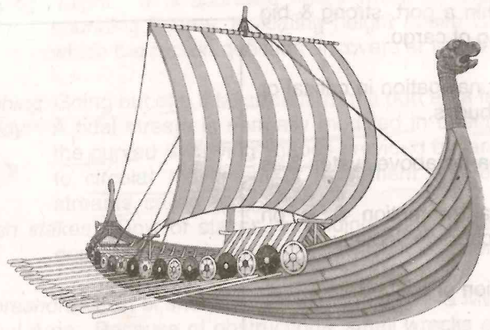
*Strait:* A narrower stretch or passage of water connecting two seas or large bodies of water.

*Watch buoy:* As name suggests normally placed near a more important navigational mark such as a light vessel to keep a check by relative positioning. Rather obsolete now.

Exercise:

*Q.1 On Admiralty charts, what symbols / abbreviations are used for following?*

*(1) Surveyed coastline.*
*(2) Cliffy coast.*
*(3) Limiting danger line.*
*(4) Foreshore rock & coral.*
*(5) Palm trees.*
*(6) Unspecified trees.*
*(7) Breakwater or mole.*
*(8) Fish trap.*
*(9) Quarantine office.*
*(10) Custom house.*
*(11) Lock.*
*(12)Anchor berth with swinging circle*
*(13) Pontoon bridge.*
*(14) Lift bridge.*
*(15) Airport airfield on large & small scale chart.*
*(16) Mosque.*
*(17) Pagoda.*
*(18) Church.*
*(19) Post office.*
*(20) Hospital.*
*(21) Lighted gas production platform.*
*(22) Tower.*
*(23) Pilot boarding place.*
*(24) Intensified, faint & obscured sector.*
*(25) Continuous ultra quick.*
*(26) Composite group flashing.*
*(27) Alternating White Red.*
*(28) Unlit E- cardinal spar buoy.*
*(29) Region A port & starboard hand pillar buoy.*
*(30) Isolated danger buoy.*
*(31) Deep water spar buoy.*
*(32) Special purpose spherical buoy.*
*(33) Data collection buoy.*
*(34) Radar reflector.*
*(35) CRS providing QTG service.*
*(36) Radio direction finding station.*
*(37) Non directional radio beacon.*
*(38) Wreck over which depth has been obtained by soundings.*
*(39) Underwater rock not dangerous for surface navigation.*
*(40) Non dangerous wreck.*
*(41) Dangerous wreck.*
*(42) Wreck of which mast only are visible on different scale chart.*
*(43) Eddies.*
*(44) Underwater rock with 2 m or less Over it at CD.*
*(45) Precautionary area.*
*(46) Submarine pipeline.*
*(47) Submarine pipeline area.*
*(48) Inshore traffic zone with defined limits.*
*(49) One way & two way DW routes.*
*(50) Flood tide stream (with rate).*



**Viking Warriors:** *People of Scandinavia used Viking ships for trade, invasion & looting activity. They virtually terrorized North seas. They built broad, roomy cargo ships called knorrs. These were the best ships of period 700AD to 1000AD. Vikings ventured transatlantic up to Greenland & even to North America. The voyage From Bergen To Newfoundland was made in 28days in spite of bad weather.*

*[Pic. Viking Long Ship, L = 24m (1000AD)]*

# Chapter 6: Buoyage System

## IALA MARITIME BUOYAGE SYSTEM

In the Dover Strait in 1971 first Brandenburg & later Niki struck the wreckage of the Texaco Caribbean and sank, in spite of adequate markings. 51 lives were lost. This disaster gave birth to IALA Maritime Buoyage System.

Many buoyage systems prevailed in different parts of world causing non-uniformity of marking of channel, dangers etc. This naturally caused confusion to the user & hence endangered safety of navigation. Technical Committee of the International Association of Lighthouse Authorities [IALA], a non-governmental body that brings together representatives from the aids to navigation services made several attempts to form a single worldwide system. Eventually it was decided that the use of only two alternative systems was practicable by dividing the world into two Regions. It proposed a system allowing the use of both Cardinal and Lateral system in each Region, but whereas in Region A the 'colour red' of the Lateral system is used to mark the port side of a channel and the 'colour green' the starboard side, in Region B the colours are reversed.

*IALA system has provisions to indicate or mark the following:*

i. Sides and centerlines of navigable channels;
ii. Navigable channels under fixed bridges;
iii. Natural dangers and other obstructions such as wrecks (which are described as 'New Dangers' when newly discovered and uncharted)
iv. Areas in which navigation may be subject to regulation
v. Other features of importance to the Mariner.

***GENERAL FEATURES:*** System provides five types of mark viz. Lateral, Cardinal, Isolated Danger, Safe Water and Special marks. They may be used in any combination. Wrecks are marked in the same way as other dangers. No unique type of mark is reserved for them in the IALA System. Red & green colours are reserved for lateral marks, yellow for special marks. Black & yellow or black & red bands, or red & white stripes, are used for other types of marks. Five basic shapes were defined when the System was devised viz. Can, Conical, Spherical, Pillar and Spar. Can, conical and spherical buoys indicate by their shape, the correct side to pass. Marks that do not rely on their shape for identification, carry the appropriate top mark whenever practicable. Can, conical, spherical and X- shaped topmarks only are used.



On pillar and spar buoys the use of top marks is particularly important. On Admiralty chart, topmarks are shown boldly, in solid black except when the topmark is red, when it is in outline only. Red and green lights of the IALA System are reserved for Lateral marks and yellow lights for Special marks. White lights, distinguished one from another by their rhythm, are used for other types of marks.

We will now discuss the characteristics of different types of mark provided by the system

### 1. Lateral marks:

Are used for well-defined channels, in conjunction with a conventional direction of buoyage. The Conventional Direction of Buoyage is defined in one of two ways.

***Local Direction Of Buoyage***. The direction taken by the Mariner when approaching a harbour, river, estuary or other waterway from seaward.

***General Direction of Buoyage***. The direction determined by the buoyage authorities, based wherever possible on the principle of following a clockwise direction around continents. It is usually given in Admiralty Sailing Directions and, if necessary, indicated on charts by the appropriate symbol.
Around the British Isle the general direction of the buoyage runs N along the west coast & through the Irish Sea; E through the English Channel and N through the North Sea.
Red and green are the colours reserved for Lateral marks. Port- hand marks carry can- shaped topmarks, and starboard - hand marks carry conical topmarks. Red and green lights are used for Lateral marks. Lateral marks for certain purpose have specified rhythms.

### 2. Cardinal marks

Cardinal marks are used in conjunction with the compass to indicate where the Mariner may find the best navigable water. They are placed in one of the four quadrant [North, South, East, West] bounded by inter-cardinal bearings, from the point marked. Cardinal marks take their name from the quadrant in which they are placed. The Mariner is safe if he passes N of a North mark, E of an East mark, S of a South mark and W of a West mark.

Cardinal marks may be used to,
a. Indicate that the deepest water in an area is on the named side of the mark.
b. Indicate the safe side on which to pass a danger.
c. Draw attention to a feature in a channel such as a bend, junction, bifurcation or end of a shoal.

Black double cone topmark is a very important feature of Cardinal marks. The topmark is carried whenever practicable, with the cones as large as possible and clearly separated. The position of the black band or bands is related to the direction of apex of the black topmark, thus;

| | |
|---|---|
| North points up | Black band above yellow band; |
| South points down | Black band below yellow band; |
| West points inward | Black band with yellow bands above and below; |
| East points outward | Black bands above and below yellow band. |

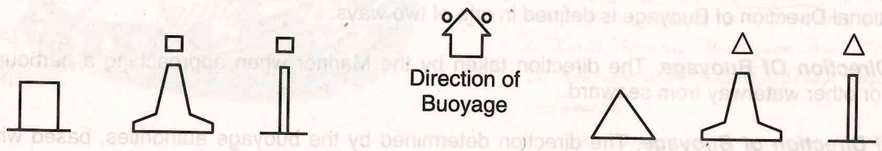
The shape of Cardinal marks is not significant, but in the case of a buoy it is a pillar or spar. White lights are exhibited from Cardinal marks, which are lighted. Their characteristics are based on a group of quick or very quick flashes, which distinguish them as Cardinal marks and indicate their quadrant.

The distinguishing quick or very quick rhythms are
North: Uninterrupted, East: 3 flashes in a group, South: 6 flashes in a group followed by a long flash, West: 9 flashes in a group.

LATERAL MARKS

REGION A

| | PORT HAND | STARBOARD HAND |
|---|---|---|
| Colour: | Red | Green |
| Shape: | Can, pillar or spar. | Conical, pillar or spar |
| Topmark: | Single red can | Single green cone pointing upwards |
| Retroreflector: | Red band or square | Green band or triangle |



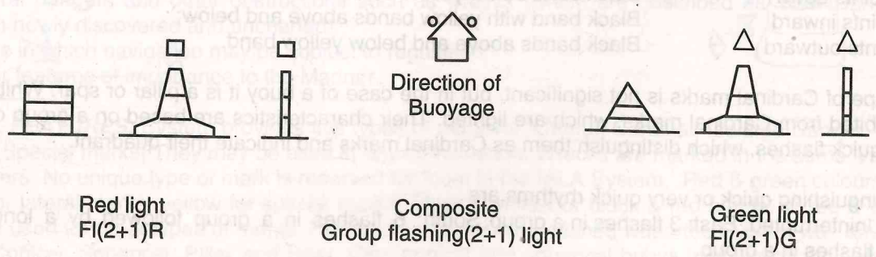

LIGHTS when fitted may have any rhythm other than composite group flashing (2+1) used on modified Lateral marks indicating a preferred channel. Examples are:

| Red light | | Green light |
|---|---|---|
| QR | Continuous quick light | QG |
| Fl R | Single flashing light | Fl G |
| L Fl R | Long flashing light | L Fl G |
| Fl(2)R | Group flashing light | Fl(2)G |

PREFERRED CHANNELS

At the point where a channel divides, when proceeding in the conventional direction of buoyage, a preferred channel is indicated by a modified port or starboard Lateral mark as follows.

| Preferred channel to starboard | | Preferred channel to port |
|---|---|---|
| Colour: | Red with one broad green band | Green with one broad red band |
| Shape: | Can, pillar or spar. | Conical, pillar or spar |
| Topmark: | Single red can | Single green cone pointing upwards |
| Retroreflector: | Red band or square | Green band or triangle |




Red light
Fl(2+1)R

Composite
Group flashing(2+1) light

Green light
Fl(2+1)G



LATERAL MARKS

REGION B

| | PORT HAND | STARBOARD HAND |
|---|---|---|
| Colour: | Green | Red |
| Shape: | Can, pillar or spar. | Conical, pillar or spar |
| Topmark: | Single green can | Single red cone pointing upwards |
| Retroreflector: | Green band or square | Red band or triangle |


LIGHTS when fitted may have ny rhythm other than composite group flashing (2+1) used on modified Lateral marks indicating a preferred channel. Examples are:

| Red light | | Green light |
|---|---|---|
| QG | Continuous quick light | QR |
| Fl G | Single flashing light | Fl R |
| L Fl G | Long flashing light | L Fl R |
| Fl(2)G | Group flashing light | Fl(2)R |

PREFERRED CHANNELS

At the point where a channel divides, when proceeding in the conventional direction of buoyage, a preferred channel is indicated by a modified port or starboard Lateral mark as follows.

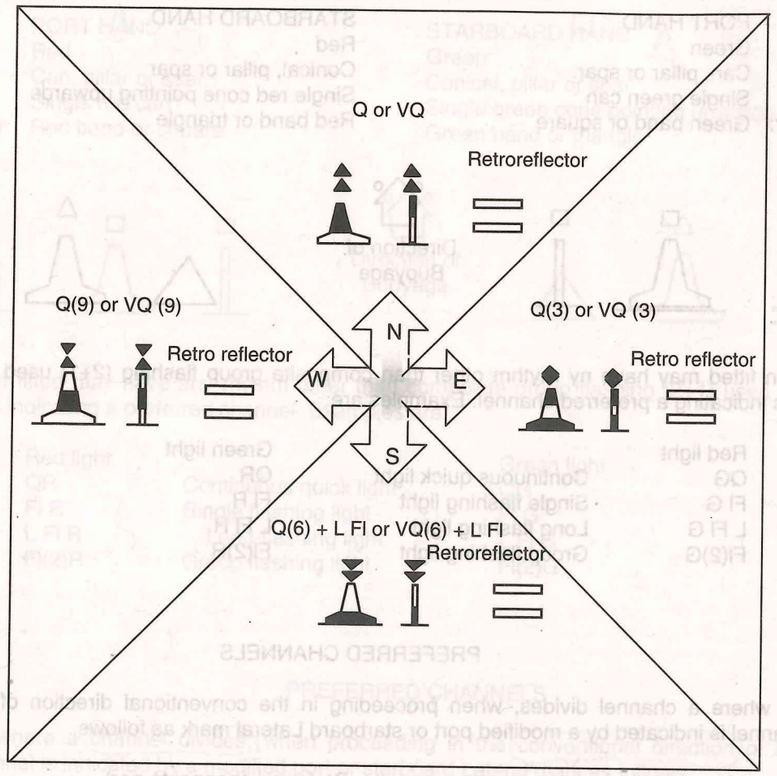
| Preferred channel to starboard | | Preferred channel to port |
|---|---|---|
| Colour: | Green with one broad red band | Red with one broad green band |
| Shape: | Can, pillar or spar. | Conical, pillar or spar |
| Topmark: | Single green can | Single red cone pointing upwards |
| Retroreflector: | Green band or square | Red band or triangle |


Green light
Fl(2+1)R

Composite
Group flashing(2+1) light

Red light
Fl(2+1)G

CARDINAL MARKS
Topmarks are always fitted (when practicable)
Buoy shapes are pillar or spar

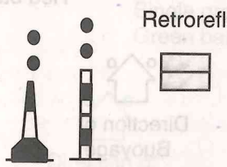



Lights when fitted are White Very Quick Lights or Quick Lights a South mark also has a long flash immediately following the quick flashes

ISOLATED DANGER MARKS

Topmark
This is very important feature by day & is fitted wherever practicable

Shape: pillar or spar

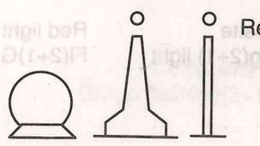


Retroreflector

Light White Group flashing(2)

SAFE WATER MARKS

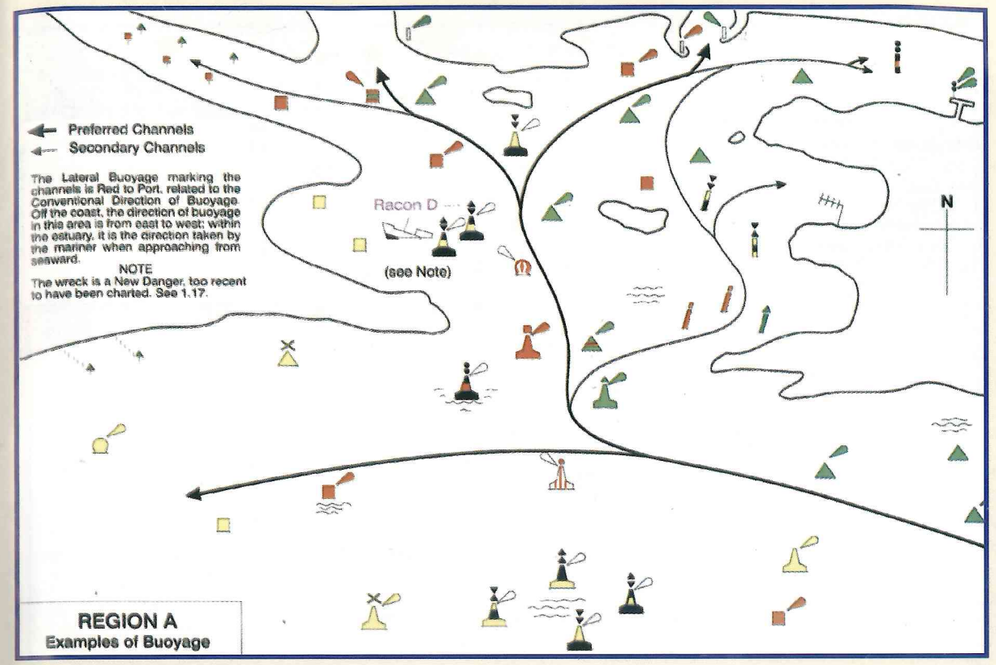
Topmark
If the buoy is not spherical this is a very important feature by day & is fitted where-ver practicable
Shape: spherical, pillar or spar.

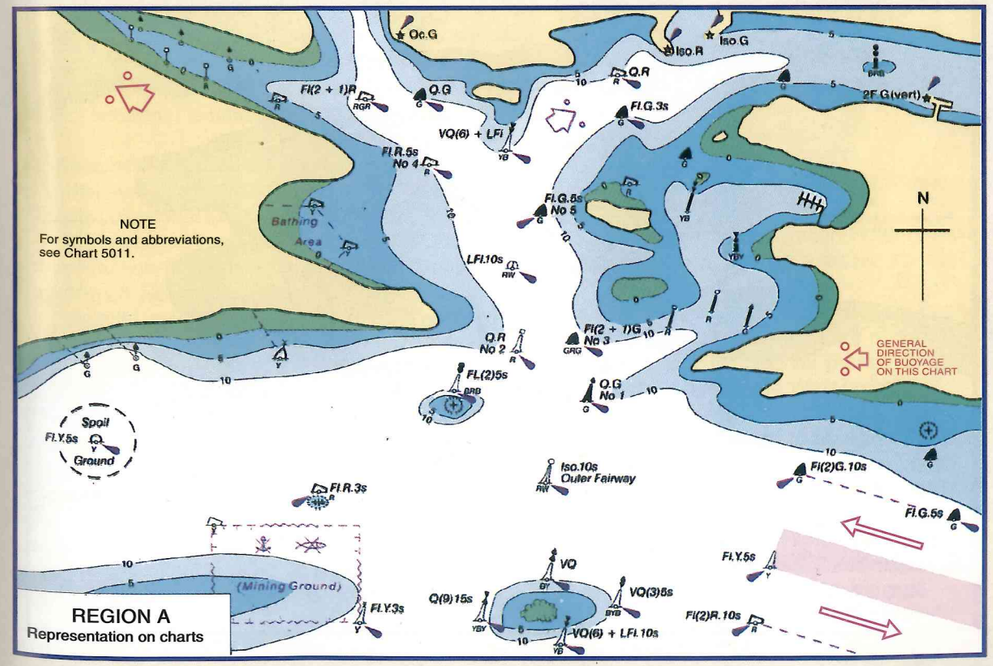


Retroreflector

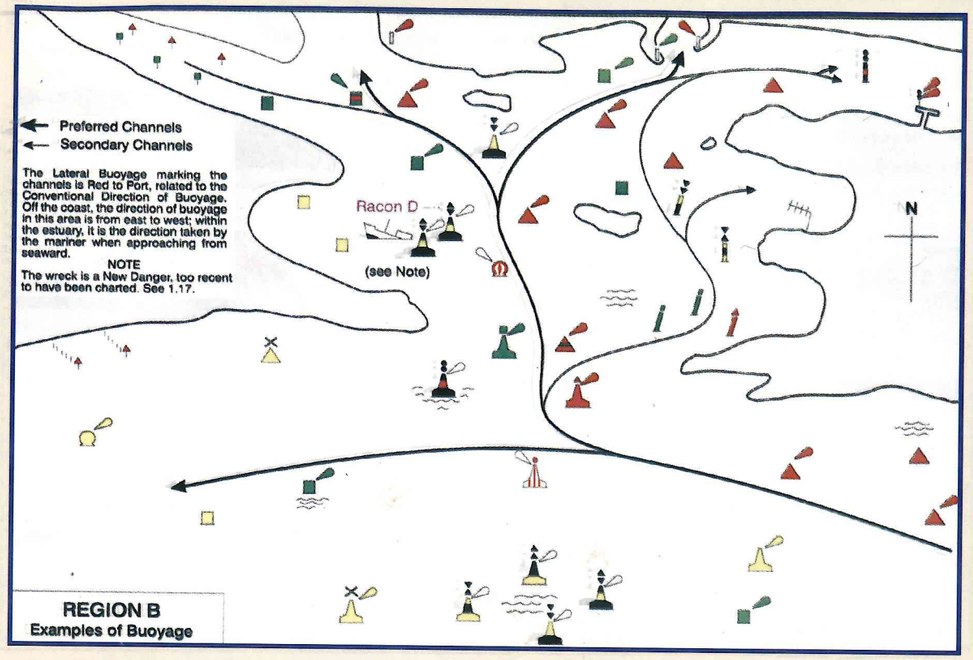
Light White isophase or Occulting or Long flashing every 10s or Morse code 'A'

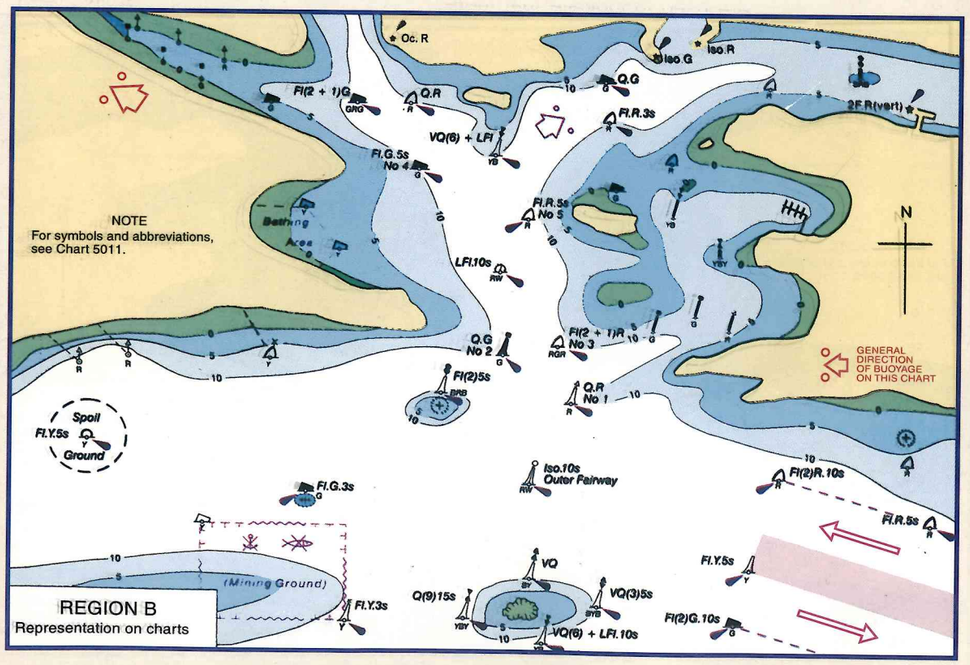
# Region A



# Region B



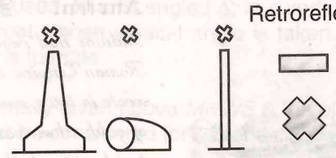





SPECIAL MARKS

Topmark (if fitted)

Shape: optional




Light: Yellow & may have any rhythm not used for White light

e.g. Fl Y, Fl(4) Y etc

If these shapes are used they will indicate the side on which the buoy should be passed.

**3. Isolated Danger marks**

Isolated Danger marks are used for isolated dangers of limited extent, which have navigable water all round them. Such a mark can, for example, indicate a shoal, which is well offshore. On Admiralty charts, the position of a danger is the centre of the symbol or sounding indicating the danger. The symbol indicating the Isolated Danger buoy will normally be slightly displaced from actual position. Black double-sphere topmarks, disposed vertically, are a very important feature of Isolated Danger marks and are carried whenever practicable. Black with one or more red bands are the colours used for Isolated Danger marks. A white flashing light showing a group of two flashes is used to denote an Isolated Danger mark.

**4. Safe Water Marks**

Safe watermarks are used to indicate that there is navigable water all round a mark. Such a mark may be used as a centreline, mid - channel or land fall buoy, or to indicate the best point of passage under a fixed bridge. Red and white stripes are used for Safe Water marks, and distinguish them from the black - banded danger - marking marks. A white light, occulting, or iso-phase, or showing a single long flash or Morse code[A] is used for Safe Water marks, when lighted. If a long flash (ie, a flash of not less then 2 seconds) is used, the period of the light is 10 second.

**5. Special marks**

Indicate to the Mariner a special area or feature, the nature of which is apparent from a chart or Sailing Directions. Or special marks may be lettered to indicate their purpose.

Thus special marks may be used to indicate, ODAS buoys, Traffic Separation Schemes where use of conventional channel marking might cause confusion, Spoil grounds, Military exercise zones, Cables or pipelines & Recreation zones.

Special marks may also be used to define a channel within a channel. For example boundaries of deep water route in channel where the limits of the channel for normal navigation are marked by red and green Lateral buoys or to mark its centre line. Yellow is the colour for Special marks. Shape used on these marks is optional, but must not conflict with that used for Lateral or Safe Water mark.

***MARKING OF NEW DANGERS:*** A new danger is a newly discovered hazard to navigation not yet shown on charts or included in sailing direction, or sufficiently promulgated by notices to mariners. The new danger may be indicated by cardinal or lateral marks. If the danger is especially grave, at least one of the marks will be duplicated as soon as practicable by an identical mark until the danger has been sufficiently promulgated. Racon showing morse code 'D' (signal length 1 mile on radar screen) & a quick or very quick light is used. In case of cardinal mark white light is used. Red or green coloured light is used for lateral mark.

**Ancient Sea Trade Of India:** *Indians had regular trade links with Arabs, Chinese, Roman Empire & Greece. The Roman historian Pling wrote in 100's, complaining that each year a vast quantity of gold, silver was spent by Roman empire to buy spices, textiles etc of India in a book called Periplus of the Erythraean sea. A sailor from Alexandria described the sea trade between India & West, including Indian ports. Archeologists confirm these descriptions. They have found a large quantity of Roman coins, pottery, glass etc at sites that were once important trading ports on Indian coast.*

*[Pic. Cargo Ships at an old Indian Port ]*

# Chapter 7: 'Position circle'
## [distance by 'vertical sextant altitude', 'horizontal angle' or radar]

Position circle means a circle of positions. It is a curve or a set of all probable positions of ship, equidistant from a point. Out at sea, it is very common to use principle of position circle to find ship's position, in day-to-day navigation. e.g. plotting of ship's position using two or three radar distances, where position is obtained at the intersection of two or three such position circles. Also plotting a position using a bearing & a distance off, position obtained is intersection of the position circle & position line.

Following are some of the common methods of obtaining position circles.

**(a) Radar Distance Off:** Normally obtained from:

i) Point of land or cape,
ii) Racon or radar reflector buoy,
iii) Nearest land which is just touching the VRM,
iv) Any point of land or a target, which is positively identified on the radar.

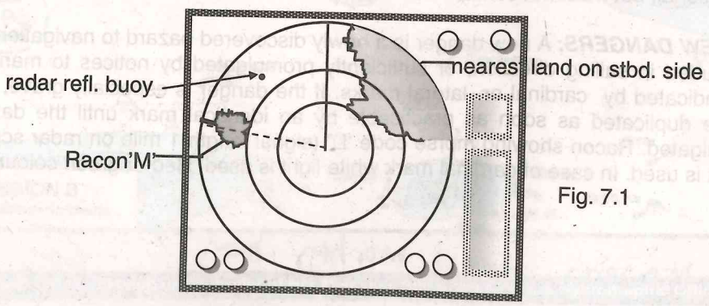



Fig. 7.1



**(b) Vertical Sextant Angle:**

Following points should be noted;

I) Principle of right angled triangle is used. In a Rt angled Δ, in a vertical plane the 90° angle is made at base of the light house or the target whose vertical angle is taken & the line joining observer & the base of target forms the base of the triangle.

ii) Height of eye is neglected.

The height of the lighthouse etc is normally given above *MHWS* & the observer may be taking the VSA at *Low Water.* Variation in tide level must be considered for better accuracy.

Formulae;

I) Distance from the base of object in Nautical Miles =

$$\frac{\text{Height of object above sea level in Meters} \times 1.854}{\text{Obs'd altitude of object in minutes}}$$

ii) Distance from the base of object in Nautical Miles =

$$\frac{\text{Height of object above sea level in feet} \times 0.565}{\text{Obs'd altitude of object in minutes}}$$

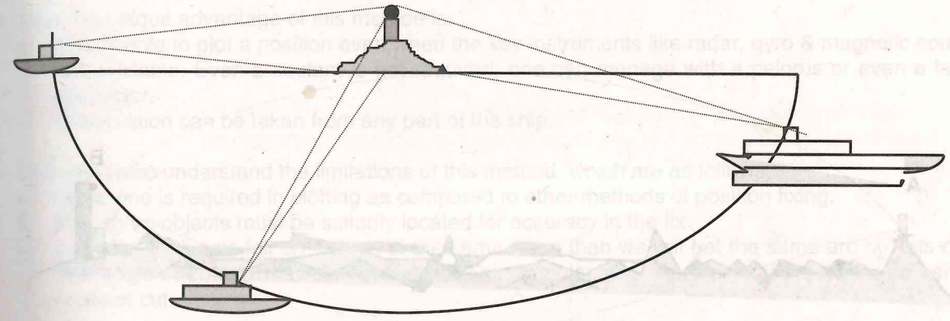


Fig. 7.2

For a given VSA vessel will lie somewhere on the circle whose radius may be found out.

(Sextant altitude in above statement means sext. alt. corrected for index error)

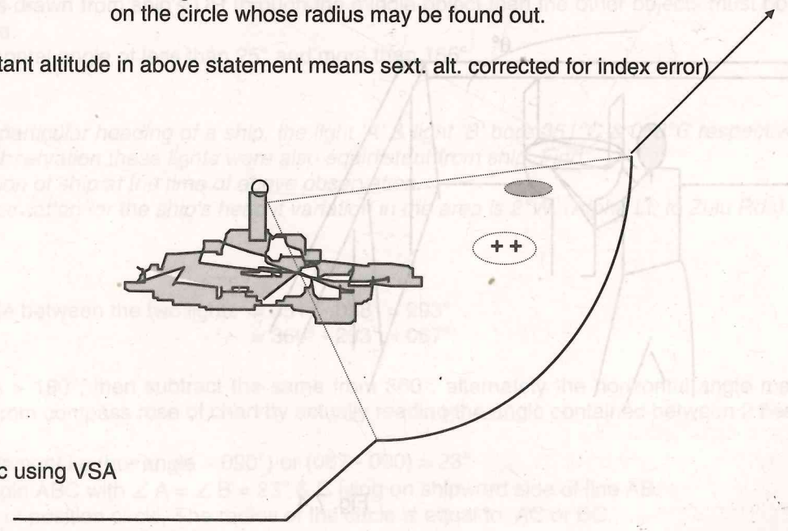


Fig. 7.3
Sailing round an arc using VSA

**(c) Horizontal Sextant (Or Azimuth, Compass, Pelorus) Angle**

The horizontal angle between any two identified charted objects may be found by each of the instruments mentioned above.

In case of *HSA* the sextant angle will need to be corrected only for index error. However this correction may be neglected for chart work purpose owing to its small value.

In case of Horizontal Compass or Pelorus Angle, one need not worry about the Compass (Standard or Gyro) error or Pelorus set for wrong ship's head. Difference of the two bearings may be straight away taken as horizontal angle.

Suppose the *Horizontal Angle* between two charted objects A & B is θ°, then centre of the position circle is found as follows:

*When θ < 90°:*

i) Draw a line joining the two lights A & B. Find angle (90-θ)°
ii) Two lines making angle of (90- θ)° are drawn at A & B respectively, to the *shipward side* of line AB.
iii) These lines will meet at say C, which is the centre of the desired position circle.

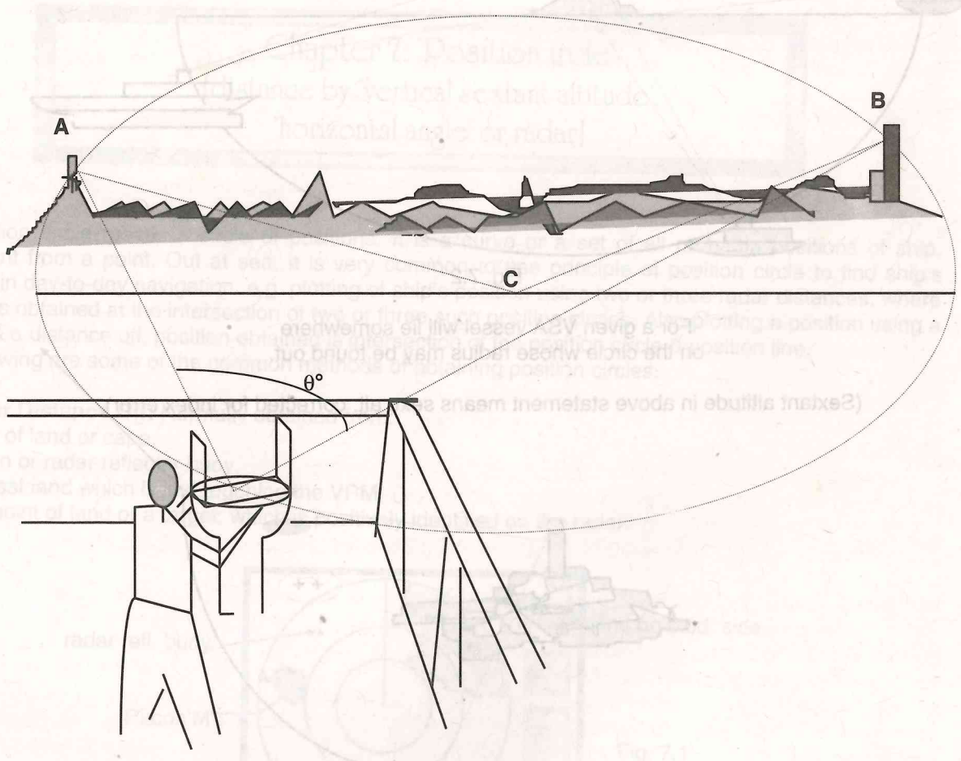



Fig. 7.4



*When θ > 90°:*

i) Draw a line joining the two lights A & B. Find angle (90-θ), which is negative in this case.
ii) Two lines, each making angle of (θ - 90)° (negative), are drawn at A & B respectively, to the *non-ship ward side* of line AB.
iii) These lines will meet at say C which is the centre of the desired position circle.The meeting point of lines C in this case will not be on the same side of the line AB as the ship but on the other side of AB. Thus Centre of position circle may be found on land in some cases.

*When θ = 90°*

The centre of position circle lies on midpoint of AB. CA = CB = radius of pos circle.
In all the three cases position circle lies on shipward side of AB & limits of arcs of circle must be enclosed with a set of single arrows.

*Note:* (a) C is always on perpendicular bisector of AB.
(b) Radius of position circle = CA = CB.
(c) Position circle passes through A, B & the observer.

Thus the unique advantage of this method is:
a. One is able to plot a position even when the key instruments like radar, gyro & magnetic compass are not available. Even a sextant is not required; one can manage with a pelorus or even a large sized protractor.
b. Observation can be taken from any part of the ship.

One must also understand the limitations of this method, which are as follows:
i. More time is required in plotting as compared to other methods of position fixing.
ii. The three objects must be suitably located for accuracy in the fix.
iii. If the three objects fall on the arc of the same circle then we will get the same arc by sets of objects. The angle of cut of the circles obtained by similarly located shore objects would give a very shallow angle of cut.

While selecting the objects for the purpose of horizontal angle, the following points may be remembered:
1. Of the 3 objects, the middle objects must be relatively closer to the ship than the other two.
2. If a circle is drawn from ship's DR through the middle object then the other objects must not be close to this circle.
3. Avoid horizontal angle of less than 25° and more than 155°.

*Q. 7.1 On a particular heading of a ship, the light 'A' & light 'B' bore 351°C & 058°C respectively. At the time of observation these lights were also equidistant from ship. Find:*
*(a) Position of ship at the time of above observation.*
*(b) The deviation for the ship's head if variation in the area is 2°W. (Alpha Lt. to Zulu Rds).*

**Procedure:**
Join A & B
Horizontal angle between the two lights = 351° - 058° = 293°
= 360° - 293° = 067°

(If hor angle is > 180°, then subtract the same from 360°, alternately the horizontal angle may also be found directly from compass rose of chart by actually reading the angle contained between 2 bearings)

Find the complement i.e.(hor angle ~ 090°) or (067 - 090) = 23°
Complete triangle ABC with ∠ A = ∠ B = 23° & C lying on shipward side of line AB.
C is the centre of position circle. The radius of the circle is equal to AC or BC.

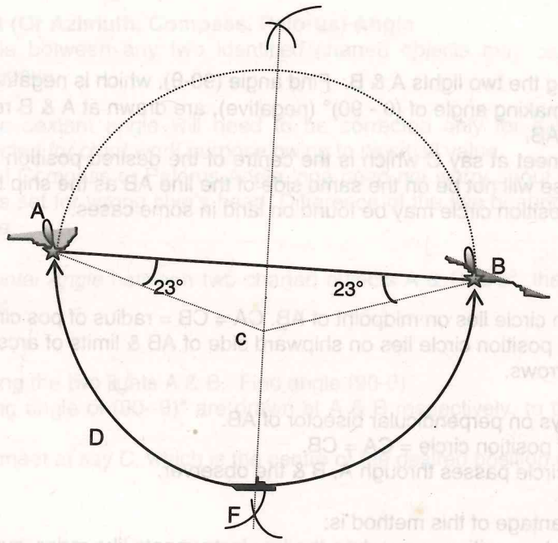



Fig. 7.5

Vessel lies on that part of the circle, which is to the shipward of line AB.
Since the vessel is equidistant from A & B, she must lie on perpendicular bisector of AB.
Position arc ADB meets at F, which is the vessel's position
**Ans. Position of vessel = 02° 18.7' N**
**080° 02.4' E**
From chart: True bearing of B = 055°
Given Compass bearing of B = 058°. ∴ Compass error = 3° W.
Since var. = 2° W ∴ *Deviation = 1° W.*

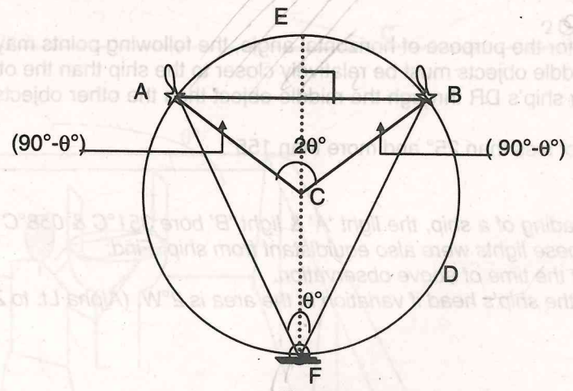



Fig. 7.6
Hor angle < 90°

**Principle:**
In fig. 7.6 & 7.7,
*Let ADBE be a circle with centre C.*
*Let AEB be an arc of this circle & let ADB be rest of the circle. AEB is the arc on the non-shipward side.*
*ADB is the arc on the shipward side, containing the ship.*
*Let F be any point somewhere on rest of the circle,ADB.*



*If arc AEB subtends an angle of θ° at this point (i.e. ∠ AFB = θ°), the same arc viz. AEB will subtend an angle = 2θ° at centre 'C'(i.e. upper∠ ACB = 2θ°).*

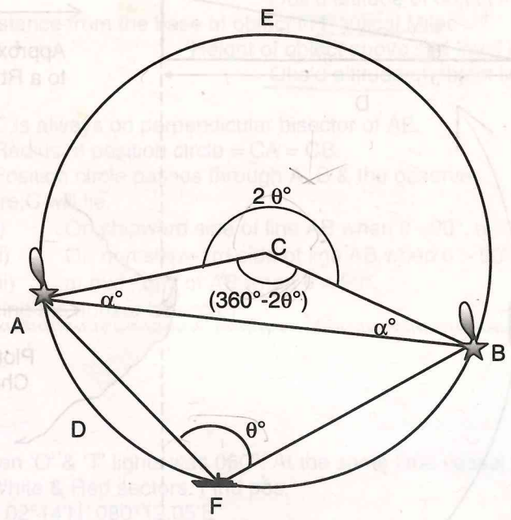



Fig. 7.7

$\alpha^\circ + \alpha^\circ + (360^\circ - 2\theta^\circ) = 180^\circ$
or $2\alpha^\circ = 180^\circ - (360^\circ - 2\theta^\circ)$
$= 2\theta^\circ - 180^\circ$
$= 2(\theta^\circ - 90^\circ)$
$\therefore \alpha = (\theta^\circ - 90^\circ)$

**Note:**
(a) C will lie (1) on shipward side of line AB when θ <90°, α = (90 - θ)°.
(2) on non shipward side of line AB when θ > 90°, α = (θ - 90)°.
(3) at mid point of AB when θ = 90°.

## To get a position circle from vertical observed altitude

*Q. 7.2 Vertical angle of a light (Ht. of light = 175feet) was 0° 51'. Find the distance of light from the ship.*

**Hint:**

$$\textit{Distance of ship from light in miles} = \frac{\textit{Ht of Lt in Ft } x\ 0.565}{\textit{Obs alt in minutes}}$$

$$\text{Thus dist in M} = \frac{175\,x\,0.565}{51}$$

**Ans. = 1.939 M**

**Principle:**
Right angled triangle. {See ans. to Q. 7(b)}

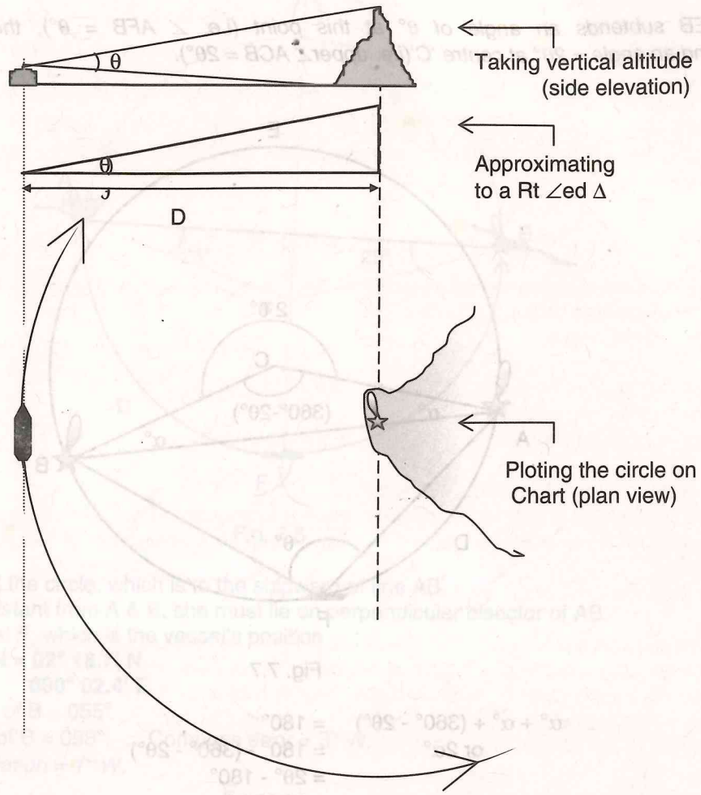



Fig. 7.9

$\tan\theta° = \frac{Height}{Distance}$. For small values of θ°, tan θ tends to become θ in radians

Or $\tan\theta° = \theta^c$, $\theta^c = \frac{\theta°}{57.3}$ radians = ht. in feet/dist in feet. $\therefore Distance\ in\ feet = \frac{ht\ in\ ft. x 57.3}{\theta}$

$$\therefore Distance\ in\ M = \frac{ht\ in\ ft\ x\ 57.3\ x\ 60}{\theta\ (in\ minutes)\ x\ 6080} = \frac{Ht\ of\ Lt\ in\ Ft\ x\ 0.565}{Obs\ alt\ in\ minutes}$$

**To find position with the help of pos circle (horizontal ∠) & sounding contour**

*Q. 7.3 A vessel after leaving Shoreham, sees Shorehm light & New Haven Radio Beacon horizontally 56° apart. Simultaneously as she steered a course of 175°T, she also crossed 30 m contour. Find ship's position at this time.*

**Hint:** Join the two lights $L_1$ & $L_2$.
Plot $CL_1$ & $CL_2$ making an angle of 34° to shipward side of $L_1L_2$, meeting at C.
Draw a circle with radius = $CL_1$ = $CL_2$, with C as centre.
This circle intersects 30 m contour at D, the position of ship.

**Ans: Pos ≡ 50°39.9'N 000°15.4'W.**



**Summary** 1) Formulae;
I) Distance from the base of object in Nautical Miles =

$$\frac{\text{Height of object above sea level in Meters x 1.854}}{\text{Obs'd altitude of object in minutes}}$$

ii) Distance from the base of object in Nautical Miles =

$$\frac{\text{Height of object above sea level in feet x 0.565}}{\text{Obs'd altitude of object in minutes}}$$

2) (a) C is always on perpendicular bisector of AB.
(b) Radius of position circle = CA = CB.
(c) Position circle passes through A, B & the observer.
3) Centre,C will lie,
(i) On shipward side of line AB when θ <90°, α = (90 - θ)°.
(ii) On non shipward side of line AB when θ > 90°, α = (θ - 90)°.
(iii) at mid point of AB when θ = 90°.
(θ being the horizontal angle)

**Exercise:**

***Alpha Light to Zulu Rds:***

Q.1 Horizontal angle between 'O' & 'T' lights was 060°. At the same time vessel was also on the common boundary of White & Red sectors. Find pos.
Ans. 02°9.5'N 080°14.5'E or 02°14'N 080°12.05'E
Q.2 Horizontal sextant angle between 'O' & 'B' light was 122°, distance of 'O' at the same time was 4.22M. Find pos of ship.
Ans. 02°16.8'N 080°10'E
Q.3 From a vessel at anchor following bearings were obtained on a steady heading. Find pos & compass error.
'M' buoy 320°C, 'N' light float 231.5°C & 'Q' 172°C.
Ans. Pos 02°5.6'N 080°14.08'E, Error 3°W.
Q.4 If observed altitude of a lighthouse of height 75m is 59', find the distance off from the lighthouse.
Ans. Distance = 75 x 1.854 / 59 = 2.36M.
Q.5 Peak of a mountain appeared 20' above water level. If height of peak indicated on chart is 700 feet, find distance of ship from the mountain.
Ans. Distance off = ht in feet x 0.565 /obs altitude in minutes =700 x 565 /20 =19.78M
Q.6 A Sextant is set to find the altitude of a mountain peak which is at a horizontal distance of 9M from ship. If the peak is 300m above sea level find the altitude set on sextant, (index error = 1.8' off the arc).
Ans. Distance = 300 x 1.854 /obs altitude. Obs altitude =300 x1.854 /9 =61.8. Sext alt =61.8 -1.8 =60'.
Q.7 Describe the position of centre and radius of position circle, in following cases,
A. Horizontal angle between lights A and B 30°.
B. Horizontal angle between lights A and B 90°.
C. Horizontal angle between lights A and B 110°.
Ans. Note; In case of 'horizontal angle position circles', centre of position circle always lies on perpendicular bisector of A- B. Additionally it will lie, in case of
A. To shipward of A B since the angle is < 90°.
B. To non- shipward side of A B, since the angle is >90°
C. At mid point of A B, if the angle is 90°.
Q.8 A vessel at quarantine anchorage found 'D' buoy bearing 256° C and 'N' racon bearing 166°C buoy M bore 061°T, find position and compass error.
Ans. Horizontal angle between D & N = 90°. Position 2° 6.9 N. 80° 9.7 E, Compass error =2.5°W.
Q.9 Vertical altitude of 'B' light was 14.1', bearing of same was 030°. Find ship's pos.
Ans: Dist 5.26M, Pos 02°17.55'N 080°4.6'E.
Q.10 Vertical alt of 'A' was found to be 31'. Nearest land was 6M, find pos.

Ans: Dist from A 7.18M, pos 02°17.37'N 080°2.1'E.

*Q11 On a certain heading 'R' bore 220'C and 'Q' bore 280'C.Diving point was in transit with "170m peak" at the same time .Find position of the ship and the compass error*

*Ans: 02'0.8'N 080' 18.2'E C error 5'E*

*Q12 From a vessel at anchor following bearings were obtained on a steady heading. Plot the compass bearings & then resolve the cocked hat to find the compass error. Also find the position of vessel. M 320°C N 245°C Q 172°C*

*Ans: Pos 02°4.3'N 080°14.5'E CE = 2.3°E (Pos outside the cocked hat)*

***Chart: South coast of Sri Lanka:***

Q.1 From ship following bearings were taken at same time on compass:
Galle Lt 335°C, Welligama Lt 045°C, Dondra Hd Lt 074°C. Find pos & compass error.

Ans: 05°50.7'N 080°17.5'E, Error = 2.33°E.

Q.2 Welligama Lt & Dondra Hd Lt were 65° apart, when vertical sext alt of Dondra Hd Lt was 11' as taken from a ship. Find pos of ship.

Ans: 05°48.7'N 080°31'E.

Q.3 Great Basses reef light & Small Basses reef light were in transit when vertical altitude of G.B. reef light was 11.5'. Find pos of ship.

Ans: Dist = 5.48M, pos 06°7.25'N081°24.7'E.

Q.4 Great Basses reef light & Small Basses reef light bore 265°C & 034°C respectively. If vertical altitude of L.B. reef light was 10.5'. Find pos of ship.

Ans: Dist = 6M, pos 06°18.55'N 081°42.65'E.

Q.5 A vessel anchored off Dondra Hd Lt Ho, observed D Hd Lt Ho & Weligama Lt Ho to bear 071°C & 335°C respectively. If vert sext angle of D Hd Lt Ho was observed to be 00°11' (IE 1' on arc). Find compass error & vessel's pos.(June,94 2nd Mate FG)

Ans: Dist = 8.7M, 05°53.25'N 080°27'E.

***Chart : English Channel***

Q1 A vessel from her anchored position, observed following bearing using magnetic compass:
a. Anvil point light 282°C b. The Needles light 026' c. St Catherine point light 082°C.Find position of ship

Ans: 50°33N 001°41'W

Q2 From a vessel at anchor, St Catherine point light bore 287.5°C, Nab Tower light 356.5°C. Nab Tower was at a distance af 9.3M.find pos of vessel & compass error.

Ans: Pos 50°30.7'N 00°56'W.Compass error =1.5°W

Q3: Horizontal angle of 68.5° was found between Fl(3)/Land's End light & Lizard point light. If nearest land in the vicinity of Lizard Pt was at a distance of 11.5M,find the ship's position. Compute vertical sextant altitude of Wolf Rk Bn (23m) from this position. Given: index error nil

Ans: 49°47.4'N 005°19'W.Vertical sextant altitude = 2'.

Q.4 Horizontal angle between Les Hanois & Little Russel (LFLWR) was read as 35° & that between Little Russel light & Casquet Lt was 68°. Find pos of vessel.

Ans. 49°42.8'N 002°37.4'W




**Indian Naval Power in past & Colonization in Pacific:** *In the second century BC Kambuswambhav from India invaded SW of Combodia, establishing a powerful dynasty, Kambuj there. This probably was the beginning of Indian colonization in the far east. In 74AD Ajishak the prime minister of Saurashtra invaded Java & established an Indian kingdom there. This spread the Indian culture in Indonesia, Borneo, Philippines etc. In the 4th century Vijaya from Bengal established Sri-Vijaya kingdom in Sumatra. In the 8th century Shailendras from Kalinga invaded & conquered all the Far East islands & established the Shailendra Empire. They maintained the power till Rajendra Chola in early 11th century defeated Shailendras.*

*[ Pic. Indian Colonies in Pacific in past ]*

# Chapter 8: Effect of Wind & Current. 'Co Steered-CMG Δ'
## [a. With current b. With current □ wind]

***Effect of current***

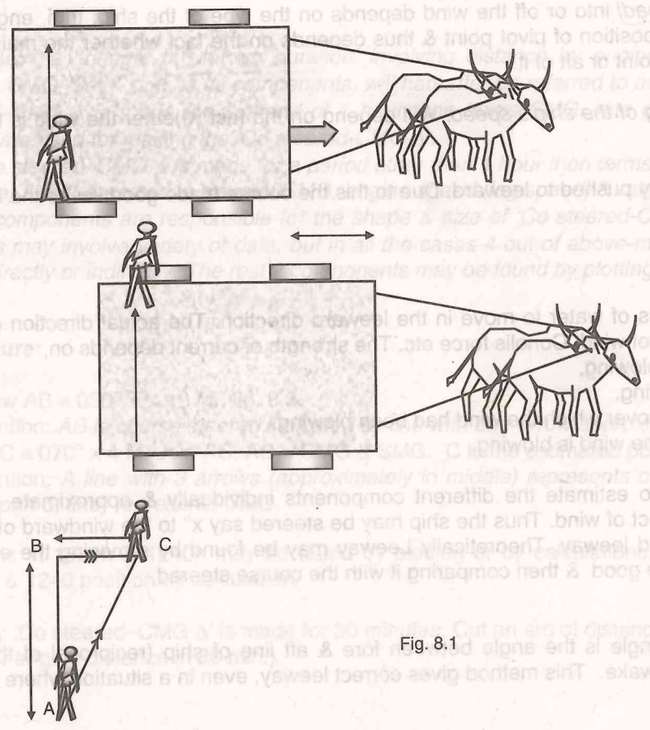



Fig. 8.1

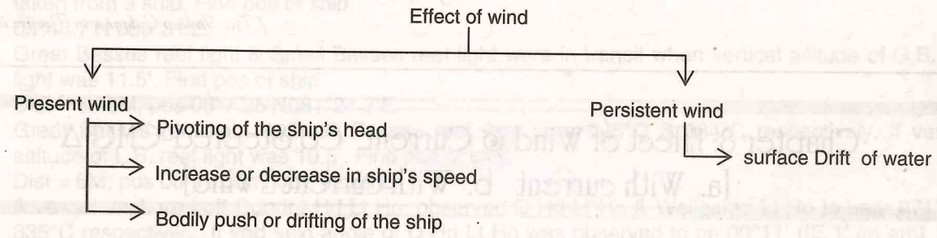
In the fig 8.1 above, a person standing on top of a cart walks in N direction for a distance of 4 units. In this time the cart underneath moves through due East by 3 units. If movement of person is considered wrt ground & not wrt cart then it can be seen that the person effectively moves in a direction, which is somewhat to East of North. Distance wrt ground is equal to 5 units.
Above illustration demonstrates the principle of *Co steered - CMG triangle.*

AB represents course steered, BC represents drift due to current in that period. AC represents course & distance made good.

The triangle ABC may be called 'Co steered - CMG triangle'. It has 6 components, viz. 3 magnitudes & 3 directions. Of which, if 4 components are known, the triangle can be completely drawn.

## Effect of wind

Wind affects the movement of the ship underway in various ways. The same may be summarized as follows.




**Present wind**

*Pivoting of the ship's head* into or off the wind depends on the type of the ship, trim, engine power etc. It also depends on the position of pivot point & thus depends on the fact whether the main windage area is forward of the pivot point or aft of it.

*Increasing or decreasing of the ship's speed:* Will depend on the fact whether the wind is favourable or against.

*Drifting:* The ship is bodily pushed to leeward. Due to this the course made good lies to the leeward of the course steered.

**Persistent Wind**

It causes the upper mass of water to move in the leeward direction. The actual direction of surface Drift will depend on direction of wind, Coriolis force etc. The strength of current depends on,
(a) consistency of the wind blowing,
(b) strength of the wind blowing,
(c) area or length of the sea over which the wind had been blowing,
(d) length of time for which the wind is blowing.

Practically it is difficult to estimate the different components individually & approximate leeway is applied to counteract the effect of wind. Thus the ship may be steered say x° to the windward of intended course, where x° is estimated leeway. Theoretically Leeway may be found by removing the element of current from the course made good & then comparing it with the course steered.

In practice the leeway angle is the angle between fore & aft line of ship (reciprocal of the course steered) and the direction of wake. This method gives correct leeway, even in a situation where current is also causing a drift.



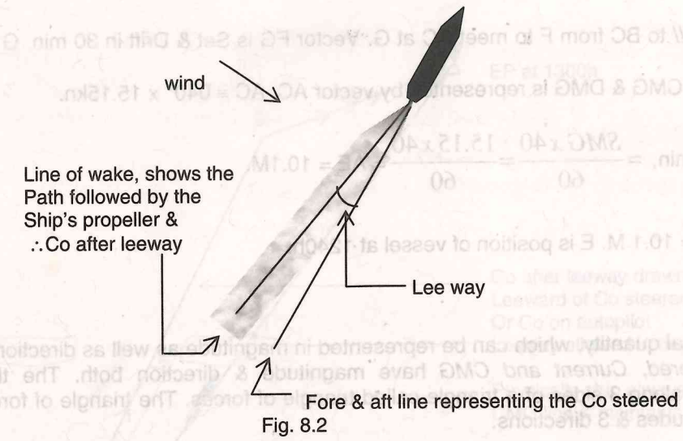



Fig. 8.2

**Given: Co steered, engine speed, direction & rate of current, wind & leeway.**
**To find Co & speed made good**

*Q. 8.1 A ship steers a course of 030° T at 12 kn on autopilot from 1200h to 1300h, Prevailing current =070°T x 4 kn*
*(a) Draw a diagram to find Course Made Good & position at 1300h Also show the position & heading of ship at 1230h & at 1240h*
*(b) What would be the course made good by ship, if, in addition to above current the wind from the starboard side is causing a leeway of 3°?*

**Ans.**

**Principle:** *A 'triangle of uniform duration' involving distance by engines, Co steered, distance over ground, CMG, Set & drift as its components, will hereafter be referred to as 'Co steered-CMG Δ'. If the co steered–CMG Δ is made for a period of 1 hour then terms SMG, rate of current & engine speed (log speed) are used for making the 'Co steered-CMG Δ'.*
*If the co steered–CMG Δ is made for a period other than 1 hour then terms DMG, Distance by engine (log distance) & drift are used in place of SMG, engine speed (log speed) & rate of current respectively.*
*The 6 components are responsible for the shape & size of 'Co steered-CMGΔ'. Problems in respect of such Δs may involve variety of data, but in all the cases 4 out of above-mentioned 6 components will be given directly or indirectly. The rest 2 components may be found by plotting.*

**Procedure:**

(a) Draw AB ≡ 030° T x 12 M., fig. 8.3.
(Convention: *AB is course steered indicated by line with one arrow approximately in middle part).*
Draw BC ≡ 070° x 4 M. Join AC. AC ≡ CMG & SMG. C is the estimated position of vessel at 1300h.
(Convention: *A line with 3 arrows (approximately in middle) represents current. A line (with 2 arrows in middle part of line) represents CMG.*

Positions at 1230h & 1240h may be found by plotting or by calculations. We will find 1230 position by plotting & 1240 position by calculation.

Plotting: 'Co steered–CMG Δ' is made for 30 minutes. Cut an arc of distance, AF = 6M on AB. (AF = 12 x 30/60 or engine distance in 30 min.)

Draw a line // to BC from F to meet AC at G. Vector FG is Set & Drift in 30 min. G is position of vessel at 1230 h.
Calculation: CMG & DMG is represented by vector AC. AC ≡ 040° x 15.15kn.

DMG in 40 min, $= \frac{SMG \, x \, 40}{60} = \frac{15.15 \, x \, 40}{60}$ = AE = 10.1M.

Cut arc AE = 10.1 M. E is position of vessel at 1240h.

**Principle:**

A physical quantity, which can be represented in magnitude as well as direction, is called Vector. The *Course steered, Current and CMG* have magnitude & direction both. The three vectors may be represented along 3 sides of a triangle called triangle of forces. The triangle of forces has 6 constituents viz. 3 magnitudes & 3 directions.

The course steered on autopilot is 030°T, represented by say AB. The ship's head at any given moment will be 030°T. Physically however, the ship is never on line AB. This is because the entire surface mass of water itself is drifting at a rate of 4 kn in a direction, 070°. The surface mass drifts in direction 070° through 2 miles in 30 min. Thus ship instead of being at F is actually at G. The ship's head at this moment is 030°. At 1240 ship is at E, the ship's head being 030°. The vessel not only moves along AC, even the speed in space or speed over sea bed is modified.. Thus AF ≠ AG & AD ≠ AE . The effective speed of ship, as can be seen from the fig. is dependent on direction & rate of current.

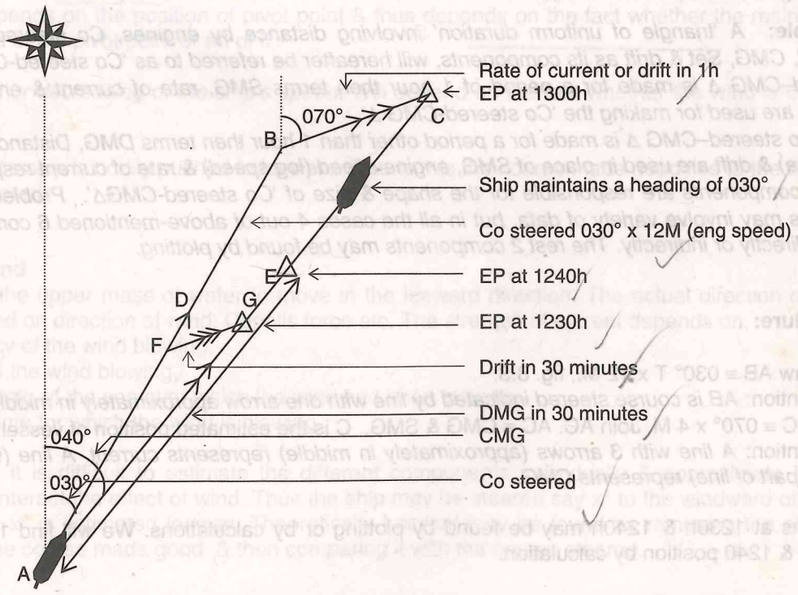



Fig 8.3



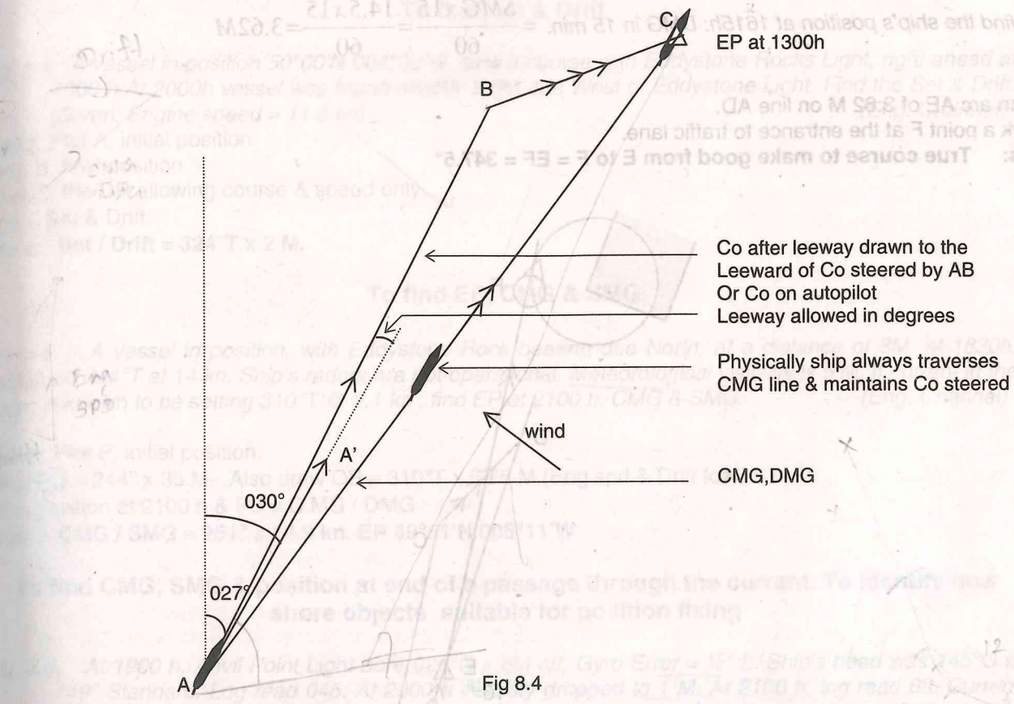



Fig 8.4

Draw AA' ≡ 030°T (Co steered) as in fig 8.4
Draw AB ≡ 027° x 12 M ( Co & Distance after the of leeway).
Draw BC ≡ 070° x 4 M. AC is CMG after the leeway & current.

**Note:** *To find position & time when a light is abeam / nearest:*

a) Abeam: Draw a line (perpendicular to course steered) through the light that is abeam. Where this line meets CMG line, is the position at which light will be abeam.
b) Nearest: Draw a line perpendicular to CMG through the light that is nearest, where this perpendicular line meets the CMG line is the position at which light is nearest. To calculate ETA at these positions or any position, the speed that must be used is *speed made good.*

## To find estimated position at the end of a time interval in prevailing current & wind

*Q. 8.2 A vessel in position 02°02' N 080°35' E at 1600h, steers a course of 000° by compass, (Var 5°W), wind E'ly estimated to cause leeway equal to 3°. Current setting NW at 3 kn Find the true course to make good at 1615 h in order to be 6 cables off from separation zone at the time of entering NW bound lane of TSS [deviation for 000°C = 5°W ship speed 12kn](Alpha Lt to Zulu Rds)*

**Hint:** Mark 1600 h position as A.
Dev = 5° W.
Var = 5° W.
Compass error = 10° W ∴ True course = 350° T.
CMG after leeway = 347° T.
To make triangle for 30 min.: Draw AB representing course steered & ship's heading.
Draw AC ≡ 347° x 6M & CD ≡ NW x 1.5 M.≡ 315° x 1.5 M.
Join AD. (AD ≡ CMG & DMG in 30 min.)
Thus CMG = 336° T & SMG = AD x 2 = 14.5 kn.

*To find the ship's position at 1615h: DMG in 15 min.* $= \frac{SMG\,x15}{60} = \frac{14.5\,x15}{60} = 3.62M$

Ct an arc AE of 3.62 M on line AD.
Mark a point F at the entrance to traffic lane.
**Ans: True course to make good from E to F = EF = 347.5°**

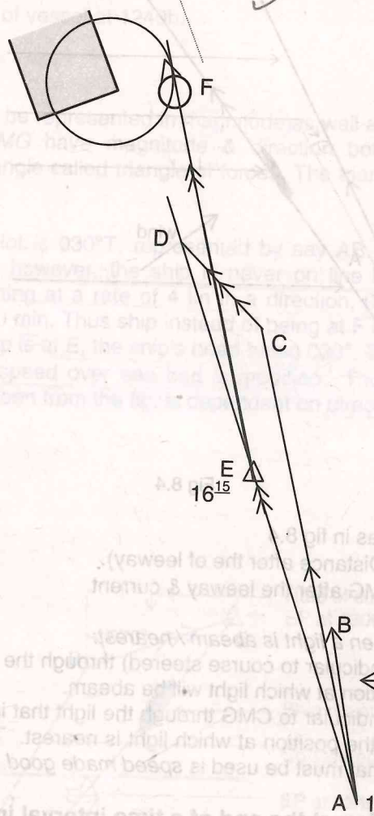



Fig. 8.5

## Given initial / final pos To find Set & rate of Drift

*Q. 8.3 A vessel 5.4 M due 'S' of EC2 buoy, at 0800 h, was steering a course of 080° by Compass (Dev 2°W). At 1000 h if the vessel was found 3' due 'S' of EC3 buoy, find Set & hourly Drift of current & Course & Speed made good by vessel. (Given: speed by log is 13 kn ) (Eng. Channel)*

**Hint:** Plot initial pos A. Var = 3°W ∴CE = 5°W.
Draw AB ≡ 075° T x 26 M.
Plot C as 1000 h position
AC is CMG ≡ 070° T & BC ≡ Set & Drift. (AC is DMG for 2 h & BC is Drift in 2 h)
**Ans: CMG = 070° T. SMG = 12 kn. Set / Hourly Drift ≡ 302° x 1.7 M.**



## To find Set & Drift

*Q. 8.4 A vessel in position 50°00'N 004°30'W, sets a course with Eddystone Rocks Light, right ahead at 1900 h At 2000h vessel was found exactly 2.5M due West of Eddystone Light. Find the Set & Drift. (Given: Engine speed = 11.8 kn) (Eng. Channel)*

**Hint:** Plot A, initial position
Plot B, final position
Plot C, the DR allowing course & speed only.
CB ≡ Set & Drift.
**Ans: Set / Drift ≡ 324°T x 2 M.**

## To find EP, CMG & SMG

*Q. 8.5 A vessel in position, with Eddystone Rock bearing due North, at a distance of 8M, at 1830h, steamed 244°T at 14 kn. Ship's radars are not operational. Meteorological visibility is 5 M. If current in the area is known to be setting 310°T @ 2.1 kn , find EP at 2100 h, CMG & SMG (Eng. Channel)*

**Hint:** Plot P, initial position.
Plot PQ ≡ 244° x 35 M. Also draw QB ≡ 310°T x 5.25 M (Eng spd & Drift for 2.5 h)
B is position at 2100 h & PB ≡ C.MG / DMG
**Ans. CMG / SMG ≡ 251° x 14.9 kn. EP 49°51'N 005°11'W**

## To find CMG, SMG & position at end of a passage through the current. To identify new shore objects suitable for position fixing

*Q. 8.6 At 1900 h, Anvil Point Light bore 026°G x 6M off, Gyro Error = ½° L. Ship's head was 145°G & 149° Standard. Log read 045. At 2000 h visibility dropped to 1 M. At 2100 h, log read 69. Current set between 1900 h & 2100 h, 121°Tx 1.6 kn Find the expected compass bearing & distance of nearest radar conspicuous target at 2100 h. Also find CMG & SMG in last 2 h (English Channel).*

**Hint:** Draw AB ≡ 145.5° x 24 M. (69 - 45 = 24)
**Ans: CMG / SMG = 142° x 13.4 kn. Compass bearing of EC1 = 254.5° x 8.4 M.**

**Summary :** *When course steered is known (To find CMG, SMG), remember!*

1) Apply leeway right away to leeward & draw →— to leeward of Co steered
2) Apply current at end of —→
3) Join initial pos with end of current vector to get CMG.

Note: 1) A light or buoy is abeam when it bears 90° to course steered.
2) A light is nearest when it bears 90° to CMG.
In either case the position of ship is on —→→— (CMG line)
3) All ETA's must be calculated @ SMG.

**Exercise**
*Chart: Alpha to Zulu Roads:*
Q.1 Vessel in position 2°24 N, 80°15 E at 0530h, steered a course of 149°G, GE 1°L. If ships speed over water is 12kn and there is a current setting 080°T at 2kn, find position of vessel at 0600. Also find CMG, SMG and time when,
1. Papa buoy will be abeam.
2. 'U'Racon will be 4 points on port bow.

Ans. Buoy P abeam at 0554h. Racon 'U' will be 4 points at 0609h. Position at 0600 02°19'N, 080° 18.95'E. CMG = 141°T SMG = 12.80kn.

Q.2 At mid night, T light bore 335°T x 2.8 M. A course of 201° was steered by gyro compass. Westerly wind was estimated to cause a leeway of 3°. Current in area set 100°T at 2kn. If ship's speed was 9kn find position at 0100h, SMG and CMG.(gyro error = 1°L)

Ans. True course steered = 202° CMG after leeway = 199°T. Position at 0100h 2°1.45N, 80°19.7 E, CMG 187°T, SMG 8.9kn.

Q.3 Course set 265°T, from 'T' pilot station, Northerly wind caused leeway of 6°. Set S 20° E @ 2 knots. Find CMG, SMG and time when 'C' will be abeam. (Ships speed is 10 knots).

Ans. CMG 248°T SMG 9.85 kn 'C' will be abeam after 1.5 hours.

***Chart: South Coast of Sri Lanka:***

Q.1 From a pos with Dondra Head Lt bearing 015°T x 7M, at 2100h, a ship steered 287°T. SW'ly wind caused leeway of 8°. Current set 140°T@ 3kn. Find CMG, SMG & pos at 2300h.(ship speed 12kn)

Ans. CMG = 287°T. SMG = 9.32kn. Pos 2300h ≡ 05°54'N 080°15.75'E.

Q.2 From a pos at 6M due S of Dondra Head Lt at 1900h, vessel steered 285°T, ship's speed 14kn. At the end of 2h vessel found Pt de Galle Lt bearing 025°T x 11M. Find set & rate of current which was effective during above 2 hours.

Ans. 'S' x 2.5kn.

Q.3 A vessel in pos, 7M due S of Dondra Hd Lt steered a Co of 275°T. If current was known to set 330°T @ 2kn & engine speed was 12kn, find: (a) Pos at end of 1h. (b) CMG (c) SMG.

Ans: (a) 05°50.7'N 080°22.5'E (b) 282°T (c) 13.25kn.

Q.4 Colombo Lt & Welikada Lt were in transit, when ship was 7.5M from Colombo Lt.. From this pos a Co, due S was steered. Current was known to set 205°T @ 3kn. Find SMG,CMG, pos at end of 1h & time when Ratmalana Lt will be abeam, given: ship's spd = 13.5kn.

Ans: SMG, 16.35kn CMG, 184.5°T pos 06°42.35'N 079°41.8'E. Lt abeam after 34.5min from start.

Q.5 Horizontal angle between Fl(3) Colombo Lt & Ratmalana Lt was 38°, at the same time Colombo Lt bore 061°T at 1800h. Find pos. From here a Co of 200° T was steered. If current was known to set 275°T x 2.5kn, find pos at 2000h, SMG & CMG. (Given: ship's speed 14kn).

Q.5a What will be CMG if W'ly wind causing a leeway of 4° was present in addition to above current?

Ans: (5) 1800h, 06°51.2'N 079°41.3'E CMG = 209.5°T, SMG 14.8kn. 2000h 06°25.2'N 079°26.8'E. (5a) CMG = 206°T.

Q.6 Little Basses reef light bore 010°T x 9.2M. From this pos a Co of 200°T was steered on autopilot. Wind on port quarter caused a leeway of 5°. Give bearing, dist & time when Great Basses reef be (a) nearest, (b) abeam. (c) Find CMG, SMG. (Given: ship's speed 13kn. Current known to set 140°T @ 2 kn.)

Ans: (a) brg 287°T at 11.35M, at 34.3 min after 1st brg. (b) brg 290°T at 11.4 after 35.4 min from 1st brg. (c) CMG 197°T SMG 14kn.

***Chart English Channel :***

Q.1 From a pos 49°45'N 00°00' at 1700h a Co of 295°T was steered for 3 hours ships speed. 14 kn. If current set due 'N' @ 2kn & SW'ly wind caused a leeway of 4° throughout, find EP at 2000h.

Ans : CMG 306°T SMG 15.1 kn pos 50°12.3'N 000°57'W.

Q.2 At 1930h Casquets light was seen in transit with Le Hanois Light at compass bearing of 210°C. Find the compass error. At the same time Cap De La Hague light bore 155°C. If she was steering a course of 071°C @ 12 kn. Find the position of ship at 2130h. The current was setting 165°T @ 2 kn throughout. Also find CMG & SMG

Ans. C.E. = 6°E CMG = 085°T SMG 12.25 kn. Pos. 50° 01'N 001° 27.3W

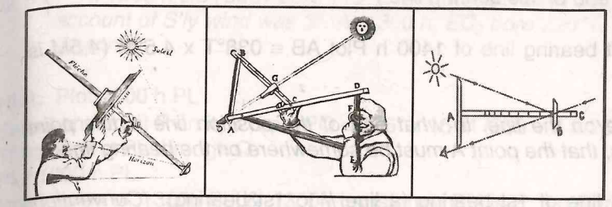
Q.3 St. Catherine's Pt was found bearing 010°T at a distance of 12 M on radar at 1030h. Ship steered a course of 250°T here after, N'ly wind caused a leeway of 8°. Current set 175°T @ 2 kn. If speed found by log was 13 kn. Find CMG, SMG & position at the end of 2 hours.

Ans. CMG = 235°, SMG = 13.9 kn Pos. 50°8.8'N 001°55.3'W

Q.4 Anvil point & Bill of Portland light houses bore 020°C & 310°C at 1000h. Ship's course was 063°C then. Deviation on the compass head was 4°E. Variation in the region was 2°W. This course was steered for next 1.5 hours at 13 kn. If SE''y wind caused a leeway of 5° & current set 310° @ 2 kn through out find the position of ship at 1130h.

Ans. CMG 051°T SMG 12.3 kn Pos. 50° 30.8' N 001° 44.6'W





**The Cross Staff:** *Derived the name from its shape. It had a staff of wood, about 3 feet long. The cross piece could be moved along it. Sizes of cross pieces was dependent upon size of back staff.*

*[Pic. 1. Back Staff 2. Davis Quadrant 3. Back-sight with Cross Staff]*

# Chapter 9: Transfer of position line & Running Fix

For plotting a fix more than a single data is necessary at the same time. Some times in want of shore based navigational aids or in want of a navigational equipment (e.g. radar), this may not be possible. The simultaneous data necessary for fixing up the ship's position may not be available. Two different bearings may be available at instants separated by an interval of time & distance.

Let us imagine a situation where:
1. Observing ship is making way through water.
2. Only one object is available for referencing the ship's position.
3. Radar is not functional. It is not possible to ascertain the distance from object.

Thus at any given moment observer could get only one position line. In such a situation observer can take two bearings at two different times, from two different positions. He can combine the useful information from the two bearings & get some idea regarding ship's position at the times when bearings were taken.

## Position by running initial position line (running fix with no current)

*Q.9.1 Quebec Lt House bore 107°T at 1400 h on a vessel steering 038° at 13.5 kn. At 1420 h same Lt house bore 172°T. Assuming that there is no current in the area, find the position of the vessel at 1400 h (Chart: Alpha Lt to Zulu Rds.)*

**Procedure:**

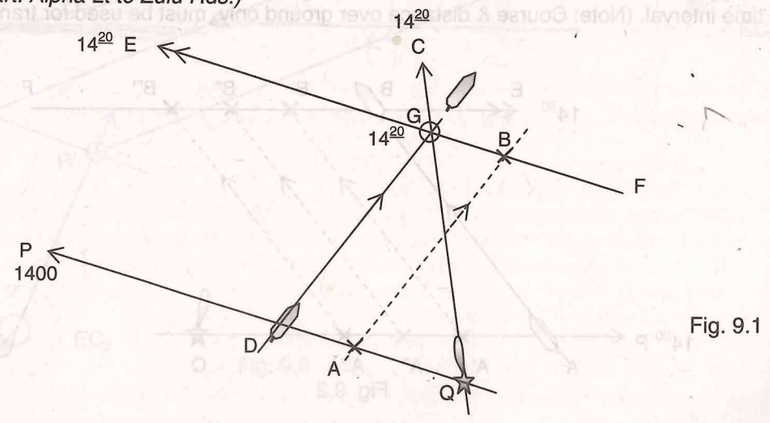



Fig. 9.1

Plot 1st bearing of light house viz. PQ = 107°T. *This is '1400 h current bearing line'.* (Convention: *Current terrestrial PL or present bearing line is drawn as a line with single arrow on shipward side. The time of observation to be entered at shipward end of this bearing line.)*

Select any convenient point A on current bearing line of 1400 h Plot AB ≡ 038°T x 4.5 M (*4.5M is 'engine distance' in 20 min.)*

*(The point A may be selected anywhere on the line. In what part of the position line is this point selected, is not important. What's important is, that the point A must be somewhere on the bearing line.)*

Through B draw the transferred position line of 1st bearing (a line // to 1st bearing). *(Convention: Transferred PL has two arrows on shipward side. The time for this PL is entered at one end of this line. Thus this line gets the time of 2nd observation but direction of 1st bearing. Thus*

$14^{\underline{20}}$ ⟸——— *means, most likely the vessel is somewhere on this line at 1420h, but this is not the current or present bearing line & this information is based on*

*(a) Some earlier observation &*
*(b) Assumption regarding course made good by the ship from that earlier observation till second observation.*

Plot 1420 h 'current bearing line CQ' with the Q light bearing 172°T.
Vessel is positively somewhere on '1420 current bearing line' at 1420 h. Ship is also most likely on '1420h transferred PL'. The common point viz. G is probable position at 1420 h
To find the position of ship at 1400 h, plot a reciprocal of CMG line from C. This line meets 1st bearing line at D. D is position of vessel at 1400h.

**Ans. Pos at 1400 h ≡ (02° 02.75'N 080°11.45'E)**

**Principle:**
In the fig. 9.2 say Q is bearing 090°T at 1400 h. It means that ship is somewhere on this line at 1400h. Ship may be at A, A', A", A"' or at any other point on the bearing line. Let the ship be steering a course of 038°T at 12 kn. Let us say that the ship was at A at 1400h. If a correct CMG & DMG for 30 minutes is applied to the point A, we get a point B. B represents the ship's position at 1430h, on assumption that she was at A at 1400h. Likewise if A',A",A"' are assumed to be the possible positions at 1400h, then the positions at 1430 would be B',B",B"' respectively. This means, if the ship was on the bearing line PQ at 1400h, she must be most likely on line EF (containing B',B",B"') at 1430h. PQ is parallel to EF. The distance between these // lines along the CMG line is the distance over the ground during the time interval. (Note: Course & distance over ground only, must be used for transfer of PL)

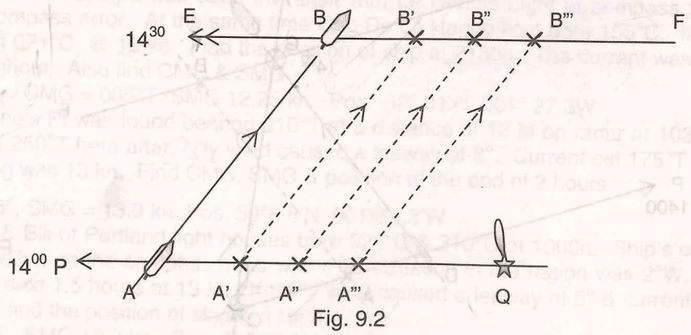


Fig. 9.2



## Running fix allowing effect of wind

*Q. 9.2 At 1200 h $EC_3$ buoy bore 115°T, ship was steering 253°T. Log speed 15kn. Leeway estimated on account of S'ly wind was 3°. At 1300 h, $EC_2$ bore 220°T. Find the position of vessel at 1300h (Eng. Channel)*

**Hint:** Plot 1200 h PL
Select any point P on it, & draw PQ ≡ 256° x 15 M (253 + 3 = 256°).
Transfer first PL through Q.
Plot 1300 h PL.
Intersection of '1300h PL' & '1300h-transferred PL' is R, the Running Fix at 1300h.

**Ans: R ≡ 50°16.5'N 001°06.5'W.**

*Q.9.3 A vessel steering a course of 259°T, found $EC_3$ bearing 115°T at 1200h. At 1300 $EC_2$ bore 200°T. Find the position of vessel at 1200 h (Given: Engine speed = 15 kn. Estimated leeway, due to N'ly wind = 3°, Current in the area was known to be setting 170° @ 2 kn ).*

**Hint:** Draw 1200 h PL.
Select any point P on it & draw PQ ≡ 259 - 3 = 256°T x 15 M
Draw QS ≡ 170° x 2 M.
Transfer initial PL, through S, for 1300 h
*R'* is the intersection of '1300 h current PL' & '1300 h transferred PL'

*To find the position at 1200 h:*
Go back // to CMG & on a course reciprocal of CMG, for a distance = distance made good in 1 hour. The point *P'* thus obtained is on the first PL & is position of vessel at 1200h.

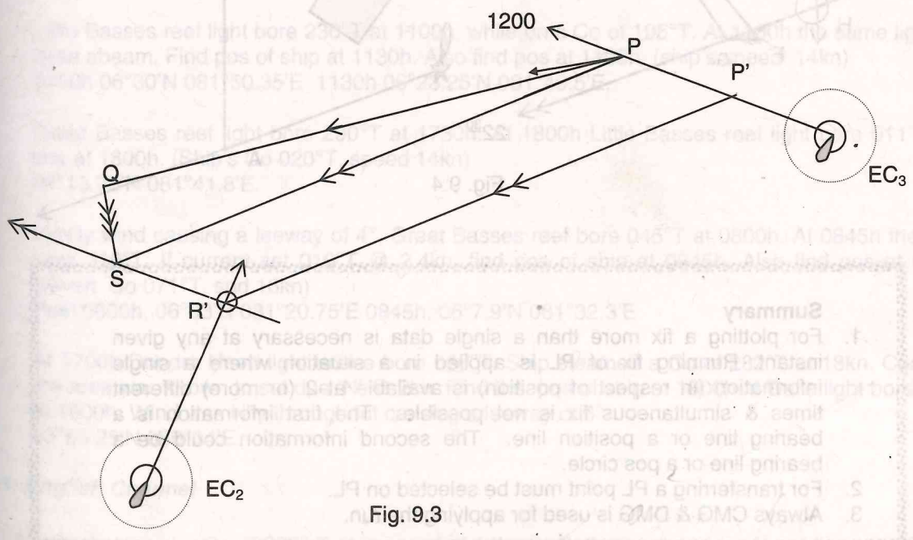


Fig. 9.3

**Ans CMG 249°T, SMOG = 15.2 kn, Pos 50°16'N 001°10.5'W**

**Transfer of position line, while vessel proceeds along different courses, to give running fix**

*Q. 9.4 Pos of vessel estimated as 26°21.5'N 056°41.3'E, on the basis of single observed bearing line of Didamar Light. Radars were inoperational. Meteorological Visibility was poor. Log was set to 001 at 1800 h. Subsequent manoeuvres were as follows.*

| *Time* | *Log* | *Course* | *Wind* | *Leeway* | *Set* | *Rate* |
|---|---|---|---|---|---|---|
| *1800 h* | *001* | *350°T* | *W x N* | *8°* | *170°T* | *2kn* |
| *1930 h* | *020* | *270°T* | *W* | *Nil* | *080°T* | *1kn* |
| *2100 h* | *033* | *240°T* | *W* | *3°* | *080°T* | *1kn* |
| *2230 h* | *050* | | | | | |

*At 2230 h Didamar Light was estimated to be 17 M off. Find position at 2230h.*

**Hint:**
Plot EP at 1800 h. The bearing of Didamar Light at 1800 h = 309°T. Select a point A on this bearing line. Draw AB ≡ (350° + 8°) = 358° x 19 M, BC ≡ 170° x 3 M (Drift), CD ≡ 270° T x 13 M, DE ≡ 080°T x 1.5 M (Drift), EF ≡ (240°.- 3°) = 237° x 17 M, FG ≡ 080°T x 1.5 M.
Transfer 1800 h PL, through G.

Draw an arc of 17 M from Didamar Light meeting the transferred PL at H. H is position of vessel at 2230h.

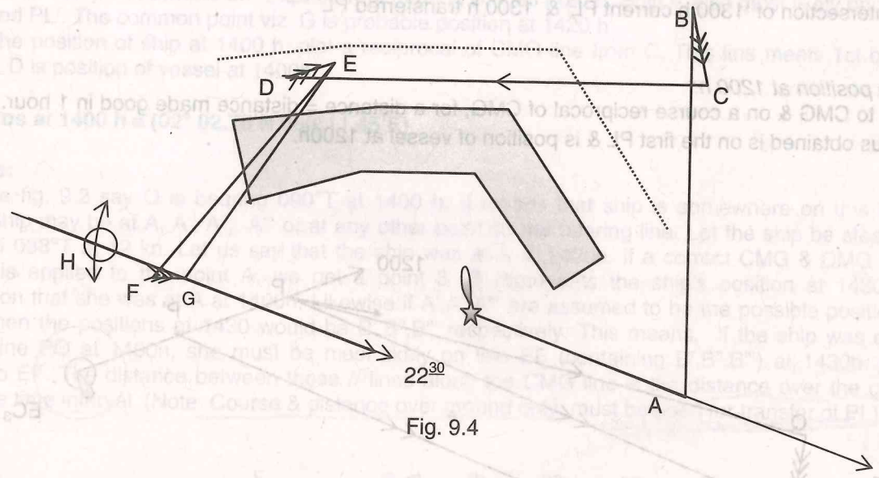



Fig. 9.4

**Summary**

1. For plotting a fix more than a single data is necessary at any given instant. Running fix of PL is applied in a situation where a single information (in respect of position) is available at 2 (or more) different times & simultaneous fix is not possible. The first information is a bearing line or a position line. The second information could be a bearing line or a pos circle.
2. For transferring a PL point must be selected on PL.
3. Always CMG & DMG is used for applying the run.



**Exercise:**

***Chart: Alpha Lt to Zulu Roads:***

Q.1 Uniform Beacon bore 307° T at 0800 hours. At 0830 h the beacon bore W. If the speed of ship was 16kn, find the position of vessel at 0800h. (Given: ships course 330°T).
Ans. 02°9.55'N, 080°33.15'E.

Q.2 At 0700h, X - ray lighthouse was found abeam on stbd side of a vessel steering 167°T. At 0730h, the same light house bore 310°T. If the ships speed was 12.2kn, find the position at 0730h.
Ans. 02°4.7'N, 080°31.5'E.

Q.3 Stranded wreck to the N of Zulu anchorage bore due West at 1800. The vessel was on a N'ly course. At 1830h X light was found 7.5 off. If speed of the vessel was 15kn, find the position of vessel at 1830h.
Ans. Position 02°9.9 N 080°33.1'E.

Q.4 At 1600h a vessel steered 160°C at 9 knots. 'T' lighthouse and 'u' beacon were in transit at this time. Transit bearing being 225°C. If Brother's Point was 7.8M off at 1730 hours, find position of ship at 1600h and 1730h. Given : current set west @ 2 knots and average tidal stream experienced by ship set 200° T @ 1.6 knots. Also find Compass error.
Ans. Compass error = 4°E Pos. 1600h 02°24.7'N 080°33.4'E
1730h 02°09.5'N 0.80°33.5'E

Q.5 At 0600h standard wreck North of Zulu anchorage bore 290°T, log read 110 then. A course of 005°T was steered. At 0700h log read 120 and at the same time the course was altered to 340°T. At 0830 h log read 133. Current estimated to set NE'ly at 2 knots in the first hour and 'E' @ 2 knots for rest of period. Find position at 0730 h and 0830 hours. Given X light bore 215°T of 0830h.
Ans. CMG in second leg = 353°T. SMG in second leg = 8.2 knots
Pos at 0830 h 02°23.8'N 080° 35.6'E, Pos at 0730 h 02°15.7'N 080° 36.55'E

***Chart: South coast of Sri Lanka:***

Q.1 Little Basses reef light bore 230°T at 1100h, while on a Co of 195°T. At 1130h the same light was seen abeam. Find pos of ship at 1130h. Also find pos at 1100h. (ship's speed 14kn)
Ans: 1100h 06°30'N 081°50.35'E 1130h 06°23.25'N 081°49.5'E.

Q.2 Great Basses reef light bore 290°T at 1730h. At 1800h Little Basses reef light bore 011°T, find pos at 1800h. (Ship's Co 020°T, speed 14kn)
Ans: 06°13.75'N 081°41.8'E.

Q.3 In N'ly wind causing a leeway of 4°, Great Basses reef bore 045°T at 0800h. At 0845h the same bore 310°T. If current set 010°T @ 2.4kn, find pos of ship at 0845h. Also find pos at 0800h. (Given Co 071°T, spd 16kn)
Ans: Pos: 0800h, 06°03'N 081°20.75'E 0845h, 06°7.9'N 081°32.3'E

Q.4 At 1700h Dondra Head light house bore 050°T. Ship steamed a Co of 282°T at 18kn. Current in the area was known to set due 'N' @ 2kn. Find the pos of ship at 1800h, if Galle light bore 350°T at 1800h. Wind was N'ly throughout causing a leeway of 6°.
Ans: 05°56.25'N 080°14'E.

***Chart: English Channel***

Q.1 A vessel steered a Co of 260° T at a speed of 14kn St Catherine light was found bearing 285°T at 1800h At 1900h same light bore 005°T, find position at 1900h.
Ans. 50°28.4'N 001°19'W.

Q.2 A vessel steered a course of 000°T at 14kn. Pte de Barfleur bore 295.5°T at 1600h & 217°T at 1645h. Find position of ship at 1600h & 1645h.

Ans. Pos, 1600h: 49°39'N001°07W. 1645h:49°49.5'N001°07'W.

Q.3 A vessel while on a course of 100°T found Casquet light to bear 200°T at 1900h. If current was known to set 010°T@ 2.5kn, from 1900h to 2100h, find ship's position at 2100h if at 2100h Pte de Barflur light bore 125°T (Given ship's speed 13.0kn)

Ans. 49°51.5'N 001°37.5'W CMG = 089°T, SMOG = 13.4 kn.



**Christopher Columbus** *[1451-1506]*

*Born in Genova in a family of wool weaver, sailed West across the Atlantic Ocean in search of a sea route to Asia. He instead made to the islands in the Caribbean Sea. During his 4 voyages between 1492 & 1504 Columbus explored present West Indies & coasts of North and South America. Columbus had done 2 major miscalculations*

*1. He understood the earth's circumference to be 25% less.*

*2. He believed most of the world consisted of land rather than water. He planned to sail 2400 miles west along latitude of Canaries to reach islands near Japan where he wanted to establish a trading town. Columbus could measure latitude using Pole star. But did not have instruments to use stars for position plotting. He had a crude quadrant & a compass. Half hour glass was used to measure time. Making land was pre-told by coastal sea weed & land based birds flying. Columbus captained Santa Maria the third vessel of three ships in expedition.*

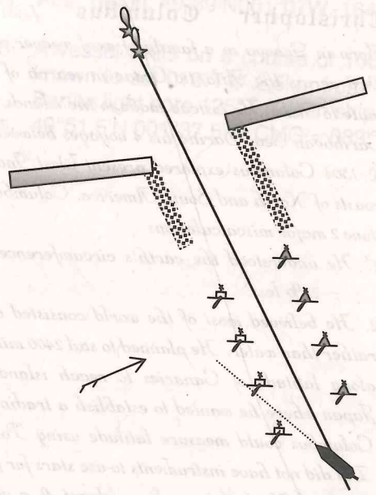
*[Pic. Columbus with his fleet incl Santa Maria]*

# Chapter 10: Co to steer & speed to steam at, [to maintain Co & / or ETA]

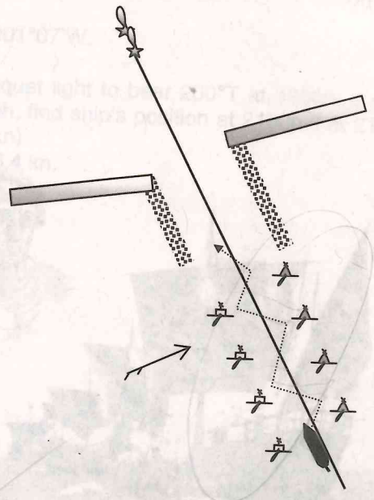
While transiting an approach channel, a pilot sometimes advises steering a course, which might appear to lead in a direction not towards the port but a little to the left or a little to the right. A new person may wonder, what's happening but pilot knows, what he is doing. This applied offset in the course steered depends on,

1. Strength of cross currents & drift force due to the wind.
2. Ship's speed.

Sometimes speed is increased to maintain the vessel in channel, when cross currents are suspected. Higher allowance for course will be required for slower ships. Course steered, engine speed, CMG & SMG maintain relationship as per 'Co steered - CMG triangle' as discussed before. Practically we do not draw & solve triangle during navigation. The construction of Co steered-CMG triangle & calculations of CTS must however be thoroughly understood by a student. The idea is that a ship handler after having understood the effect of current & wind is able to visualize & construct imaginary 'Co steered - CMG triangle' in his mind & allow right amount of offset to the Co to make good. For critical cases he may calculate CTS by construction.



Course steered to maintain the ship's position in the middle of channel
Fig. 10.1



Courses steered by inexperienced ship handler
Fig. 10.2

**Given: Co to make good, current, speed over water, leeway. To find Co to steer to counteract current & wind**

*Q. 10.1 What course will have to be steered in order to make good a course of 250°T in an area where*
*(a) Current is known to be setting SXE at 3 kn*
*(b) SE'ly wind is causing a leeway of 4°. (Speed over water = 12 kn).*

**Procedure:**

(a) Draw AB = 250° T (desired course or course to make good). Draw current vector viz. AC ≡ 168¾° x 3 M.(hourly Drift = 3M).
From C cutan arc of 12 M (distance by engines in 1 hour) on AB, meeting line AB at D.
CD is course to steer to make good a course of 250° T counteracting the current setting SxE.
AD is the speed made good.

(b) Since wind is SE'ly. i.e. from port side, a course which is 4° to port of CD will have to be steered in order to counteract current & leeway.

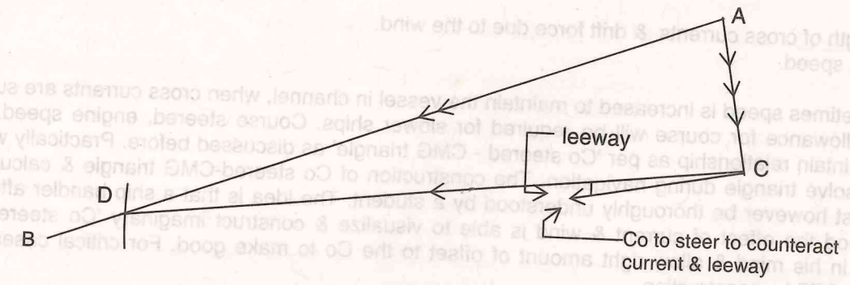



Fig. 10.3



**Note:**
(a) Compare the working with situation in chapter 8 regarding the placing of current vector.
(b) In all the cases vessel, moves along CMG or Co to MG i.e. physically ship is on CMG line & not on Co steered line.
(c) By points of compass from S to E are S, SxE, SSE, SExS, SExE, ESE, ExS & E with an angle of 11¼° between adjacent points.
(d) Wind SxE means that wind is *blowing from* SxE'ly direction. Current SxEmeans current *setting towards* SxE.

## To find Co to steer to counteract current & leeway

*Q. 10.2 A vessel in position 02°05.4' N 086°33.8'E at 1630 h wishes to join the NW bound lane of TSS, so that at the time of entering the TSS, she is 6 cables off the separation zone. If ship's speed is 10 kn & current is setting NE at 2 kn, wind E'ly, leeway expected is 2°. Find the course to steer to make good above course & time which is reported as 'time of entering TSS' (Alpha Lt. to Zulu Rds.)*

**Hint:** Plot initial position E.
At entrance to TSS mark a point 6" from separation zone.
Join EF = course to make good.
Let us make a 'Co steered–CMG Δ' of 30 minutes.
Draw EG ≡ NE x 1M ≡ 045° x 1M (Drift for 30 min = 1 M)
Cut an arc of GH = 5 M (engine distance in 30 min = 5 M)
Join GH. GH represents course to steer to counteract current ≡ 338°.
Since leeway = 2°, *course to steer to counteract current + leeway = 340°.*
EH ≡ 347.5° x 5.45 M ∴ SMG = 5.45 x 2 10.9 kn.
DTG to TSS = 6.3 M ∴ time taken to reach TSS = 34.7 min.

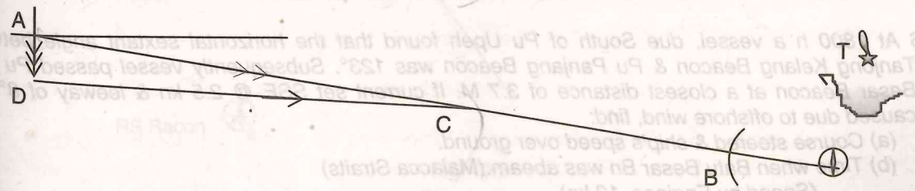
**Ans: Course to steer to counteract current + leeway = 340°. ETA at the limit of TSS = 1704.7 h.**

## Co to steer & speed to motor at, in order to make good a Co & speed

*Q. 10.3 A vessel approaching 'Tango' port is in position 02°15' N 080°00'E at 0400h. Tango pilot will be boarding at 0615h, hence the course & speed is to be adjusted to arrive 3 M off pilot boarding point, along the approach line at 0600 h Current is known to set S'ly at 1 kn. Find course to steer & speed to be adjusted to achieve above. (Alpha Lt. to Zulu Rds.)*

**Hint:** Plot initial position 'A'. (See fig)
Draw a line from A to pilot boarding point.
Mark 'B' , a point on above line at a distance 3 M from pilot boarding point.
Thus co. to make good = 099°T.
AB = distance to make good = 16.1 M.
Speed to make good = 8.05 kn
Cut an arc AC = 8.05 M on AB.
Plot AD ≡ 180°x1 M ≡ drift due to current for 1 h.
Join DC, which represents co. to steer & speed to steam at.

**Ans Co to steer = 092°T. speed to steam at = 7.9 kn.**




.Fig. 10.4

## To find Co to steer

*Q.10.4 A vessel 5.4 M due 'S' of EC2 buoy, at 0800 h, was steering a course of 080° by Compass (Dev 2°W). At 1000 h if the vessel was found 3M due 'S' of EC3 buoy, find Set & hourly Drift of current & Course & Speed made good by vessel. (Given: speed by log is 13 kn )From the position at 1000 h, find a Co to steer to pass Greenwich Buoy, 5M off on Port side. Current is likely to Set 065°T @ 2 kn after 1000h. (Eng. Channel)*

**Hint:** -Draw an arc of radius 5 M, with Greenwich buoy as centre.
Draw CD as tangent to this arc, so that buoy will be passed on Port side.
CD = Co to MG = 080° T.
Draw CE ≡ 065° T x 2 M
Cut an arc EF = 13 M. EF = Co to steer = 082°.

**Ans: Co to Steer = 082°.**

## To find Co to steer & abeam time in prevailing current & wind

*Q.10.5 Given Engine speed 12 kn , a vessel in position 50°00'N 004°30'W, at 1400 h, has to pass Lizzard Point through a position, 3 M due 'S' of it, if;*
*Case I: Current sets NW @ 1.5 kn*
*Case II: Current sets NW @ 1.5 kn & N'ly wind causes leeway of 3°.*
*Find the time when Lizzard Point Light House will be abeam in the two situations. (Eng. Channel).*

**Hint:** *Case I:*
Plot 1400 h position A.
Plot the position 3 miles due 'S' of Lizzard Point as B.
AB = Co to MG.
Plot AC ≡ 315° x 1.5 M.
Cut arc CD = 12 M.
CD = Co to steer to counteract current = 251.5°T.
Plot (251.5 + 90)° = 341.5°T (a line along direction = 341.5° with light house on it or along [341.5 - 180 =161.5°T] from light house. The position where this bearing line cuts the Co to MG, is the position, from where the light house will be seen abeam. Name this position E.
SMG = 12.7 kn.
DE = 13.2 kn ∴ Light Ho. abeam at 1603.2 h

**Ans: Co to Steer = 251.5°T. Lt Ho abeam at 1603.2 h.**

**Case II:**
Beam bearing of light house will be 90° from Co steered. Position of ship, however is always on the course made good line.

**Ans: Co to counteract Current & Leeway = 251.5 + 3 = 254.5°T. Light House abeam at 1604 h**

## To plot ship's pos using horizontal angle + 1 bearing line. Given CMG, to find Co steered & abeam position

*Q.10.6 At 1800 h a vessel, due South of Pu Upeh found that the horizontal sextant angle between Tanjong Kelang Beacon & Pu Panjang Beacon was 123°. Subsequently vessel passed Pu Batu Besar Beacon at a closest distance of 3.7 M. If current set SSE @ 2.5 kn & leeway of 8° was caused due to offshore wind, find:*
*(a) Course steered & ship's speed over ground.*
*(b) Time when Batu Besar Bn was abeam.(Malacca Straits)*
*(Speed by Engines, 12 kn)*



**Hint:** Plot the 1800 h position. Call it P.
Draw an arc of 3.7 M, with Pu Batu Besar Bn as centre.
From 1800 h position draw a tangent on this arc, giving CMG.
To find time when abeam, draw ⊥ar to course steered & extend the same till CMG, meeting at say Q.
Find time required to reach Q @ SMG.

**Ans: (a) Course steered = 308°T. Speed over ground 10 kn. (b) 1900 h.**

## To find ship's pos using Horizontal angle & trigonometric properties of a right angled triangle. To find out deviation of compass, on a heading. Getting two objects on opposition or reciprocal bearings

*Q. 10.7 At 1745 h Batu Mandi Light & Batu Besar Light bore 007°C & 097°C respectively on a certain heading. Vessel's distance from Batu Mandi Light is half the distance from Batu Besar Light.*
*Find the compass error on that heading.*
*If from 1745 h position a true course of 136° is steered,(Dev 3°W on the head). What time will the vessel have Releigh Shoal Racon & Batu Besar Beacon in opposition.*
*What will the Batu Besar Bn bear by compass then.(Ship's speed 12 kn.) [Malacca Straits]*

**Hint:**
Horizontal angle = 090°, which means the centre of position circle, C is the midpoint of the two lights, M & B. & also the radius of the circle = ½ the distance between the two lights. Also diameter subtends an angle = 90° at any point on circumference. Thus MBD is a right angled triangle.
MD / BD = tan ∠ B = ½. Giving ∠ B = 26.5°.
Plot 1745 h position as above.
True bearing of Batu Mandi Light = 010°. Thus C.Error = 3°E.
Dev = 3°W, Var = 1¾ °W & Compass error = 4 ¾ °W.
Plot a course of 136°T from 1745 h position.
At E, RS Racon & BS Bn are in opposition. (All the three are in line with the two lights on opposite sides).

**Ans: Dev = 3°E., True bearing = 048°. Compass bearing = 052 ¾ °. Time of opposition transit = 1816 h.**

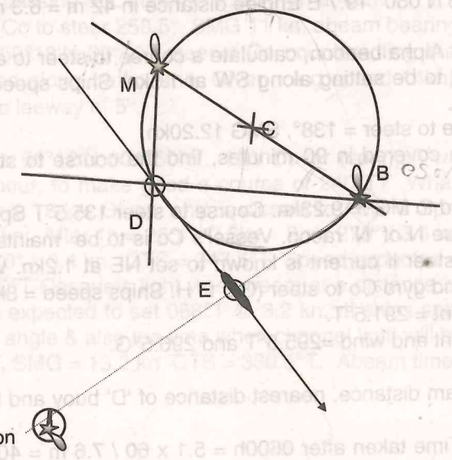



Fig. 10.5

### To find the Co to steer & speed to steam at in order to maintain the required eta in prevailing current

*Q. 10.8 A vessel in position, 4 M due West of EC$_1$ Buoy, at 0400 h, wishes to reach 3 M due South of Needles Pilot boarding position at 0730 h If average current expected during the passage is SSE x 2 kn & maximum engine speed is 13 kn. Find the engine speed to proceed at & the course to steer to make good the desired ETA? (English Channel)*

**Hint:**
Plot initial position, J & final position K. JK represents course to make good & distance to make good in 3.5 h
Draw JL ≡ 157.5° x 7 M. LK gives the distance steamed by engines or log distance in 3 h = 35.6 M.

**Ans: Co to steer = 010°T. Engine speed = 10.2 kn.**

**Summary:** In order to find CTS, leeway is not considered for making triangle. The first line that normally is drawn is AB, the Co to M.G. i.e. ⇛ Current vector ⇛ is placed at the beginning starting from A (i.e. AC). From end of current i.e. 'C' a line representing course steered or engine speed is drawn till CMG line. To counteract wind a course further to the windward is steered.

**Exercise:**

***Chart: Alpha Lt to Zulu Roads:***

Q.1 At midnight T light bore 335°T x 2.8 miles. A course of 202°T was steered with westerly wind causing a leeway of 3°, Current in area set 100° T@ 2knots. If speed over water was 9 knots, find position at 0100h, SMG & CMG.
In the above passage at 0100 wind subsided, current also changed in strength & direction hereafter. Course was altered at 0100h to 254°T. If R light was found closest & 1.5M off on port side at 0142h ,find the current which acted on ship from 0100h to 42h.

Ans. Position at 0100 hour 02°1.45'N 080° 19.7'E Engine distance in 42 m = 6.3 m, set 152°T, rate 1.1 x 60 / 42 = 1.57 kn.

Q.2 From a position, 3 M due S of Alpha beacon, calculate a course to steer to a position 2M, due N of 'L' buoy. Current is assumed to be setting along SW at 1.5kn. Ships speed 12kn. Find course to MG, course to steer and SMG.

Ans. Course to MG = 145°T, Course to steer = 138°, SMG 12.20kn.

Q.3 If the above distance is to be covered in 90 minutes, find the course to steer and engine speed required do it.

Ans. Total distance = 13.85 M speed to MG = 9.23kn. Course to steer 135.5°T Spd to steam 9.33kn.

Q.4 A vessel at 0600h was 1 M due N of 'N' racon. Vessel's Co is to be maintained along the lane in which she is. Find the Co to steer if current is known to set NE at 1.2kn. Wind is N'ly, leeway is estimated to be equal to 4°. Find gyro Co to steer (GE 1° H. Ships speed = 8kn).

Ans. Co to steer to counteract current = 291.5°T.
Co to steer to counteract current and wind =295.5°T and 296.5°G.
CMG = 300° T, SMG = 7.6kn.

Q.5 In the above passage, find beam distance, nearest distance of 'D' buoy and the time of occurrence of above.

Ans. Nearest distance 7.4 cables. Time taken after 0600h = 5.1 x 60 / 7.6 m = 40.2m from 0600 i.e. at 06 h 40 min. Beam distance 7.4 cables. Time taken after 0600h =5.2 x 60 /7.6 =41.05 from 0600, i.e. at 06h 41 min.



***Chart: South Coast of Sri Lanka***

Q.1 Pos of ship by GPS: 05°50'N 081°00'E. Current setting, SE @ 3kn. Find a Co to steer to reach midpoint of entrance to westbound traffic lane. What is SMG & ETA TSS? What should be the Co thereafter in order to cause the vessel maintain // to traffic lane. (Ship's speed 13.5kn)

Ans: 1. 275.5°T, SMG 11.3kn, ETA 01h 54.4m after start 2. 279°T.

Q.2 Rassamunai point was 9M off, Dondra head point at 6M at 0600h. . From here find a Co to steer which will allow Galle light to be passed on starboard side at 6M. Find time & bearing when Rassamunai pt will be abeam. (Given: current: 200°T x 2.5kn speed 12kn).

Q.2(b) What Co will have to be steered if starboard side wind caused leeway of 4°?

Ans: (a) Co 296.5°T. Bearing = 026.5°T at 0642h. (b) 300.5°T.

Q.3 A vessel, 20M due W of Beruwala point (NW edge) has to reach in a position, 5M due W of Colombo light Fl (3) 25M, in 2h. If current in area set 290°T x 2kn, find Co to steer & engine speed if starboard side wind caused leeway of 4°?

Ans: 22.5°+ 4° = 26.5°, 14.25kn.

Q.4 From pos 06°30'N 079°30'E, a vessel has to reach a pos, 5M due W of Colombo Lt, in 2 hours. Find Co to steer & speed to steam at. Given : wind NW'ly, leeway estimated to be 5°. Current estimated to set NE @ 2kn..

Ans Final pos ≡ 06°56.2'N 079°45.25'E. Distance to MG = 30.2M. Co to MG = 30.5°T. Co to counteract current = 028°T. Co steered to counteract current & leeway = 023°T.

Q.5 A vessel steering 045°T observes Great Basses reef light to bear due N at 0800h & at 0900h it bore 287°T. (Given: current was setting 187°T @ 3kn,Speed 12kn) find:
(a) Pos at 0900h. (b) CMG & SMG (c) Co to steer to pass Little Basses reef 5M off, counteracting the current. (d) Time when L.B.reef light will be abeam. (April,94 2nd Mate FG)

Ans: (a) 06°8.55'N 081°36.8'E (b) CMG, 055.5°T, SMG, 10kn (c) Co 32°T, SMG 9.3kn (d) 1051h.

Q.6 At 2000h a vessel steering 295°C observes Dondra Hd Lt Ho to bear 070°C, Weligama Lt Ho bore 005°C & Galle Lt Ho bore 315°C at same time. Find the vessel's pos & true Co to steer to pass 7M due 'S' of Galle Lt Ho counteracting a current setting 140°T @ 2kn. 'S'ly wind causing a leeway of 3°, given: speed 12kn. (April,94 2nd Mate FG)

Ans: 05°50.8'N 080°25.15'E, Co to MG 286.5°, Co to count. current & wind 289°T.

***Chart: Eng. Channel:***

Q.1 From position 50°30°N 00°00 at 1800h, set a Co to reach a point, which is 10M due SE of Bill of Port land light, If current was estimated to set NE @ 2.5kn & speed by engine, 13kn find following: Co to make good, Co to steer to counteract current, expected speed that the ship will make good, time & bearing of passing St Catherine light when abeam.

Ans. Co to MG 266°T, Co to steer 258.5°, SMG 11 kn, abeam bearing 348.5°T, time 2222h.

Q.2 From a position 50°18'N 00°00', steer a Co counteracting the current & leeway to maintain the course made good along traffic lane. Given : log speed 14kn, current 170°T x 2Kn, N'ly wind is expected to cause leeway of 5°.

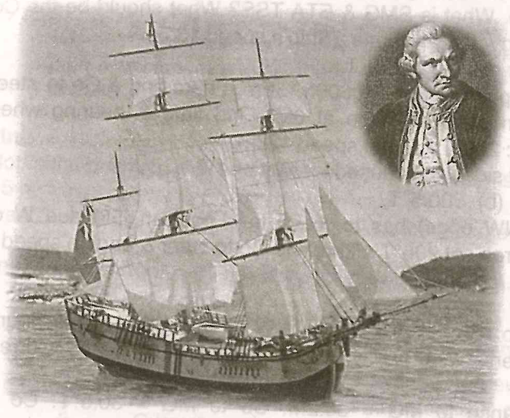
Ans. 060 $^1/_2$°T

Q.3 1800 position was 50°12'N 001°50'W. HW Dover (springs) was at 1600h. What course will you steer for next 1 hour, to make good a course of 240°T? What speed you expect to make good? speed over water is 13 kn. Given: ship is closest to ◇M◇ & Spring tidal streams at above locations are HW 238° 0.7kn After 1h = 263° / 2.3kn 2h = 270° / 3.4 kn 3h = 266° / 3.3 kn.

Ans. Tidal stream = 270° x 3.4 kn. CTS = 247.5°T. Speed expected = 10.1 kn

Q.4 Ship's course 000°T Casquets light was abeam at a distance of 10 miles at 0900h. Tidal streams for next 1 hour is expected to set 068°T @ 3.2 kn. If ships speed is 13 kn find a CTS to cross the traffic lane at 90° angle & also the time when channel light will be abeam.

Ans. CTMG = 344.5°T, SMG = 13.2 kn CTS = 330.5°T. Abeam time 1010h.



**Capt James Cook:** *[1728 – 1779] Born in a small village in Yorkshire. His father was a farm labourer. He was one of the greatest explorers of modern world. He sailed around the world twice. He was the first European to arrive at east coast of Australia in 1770. His voyages lead to establishment of European colonies through out the Pacific region. During his three voyages to Pacific he developed charts, which contributed a lot to the knowledge of basic geography of the ocean . He was murdered on 14th Feb 1779 by natives in Hawaiian islands. Capt cook made his historic voyage to New Zealand on HMS Endeavour, an Admiralty ship mere 32m long & 9m broad. This ship's staff included scientists & astronomers. Cook made the voyage from Plymouth to Tahiti via Cap Horn in about 8 months.*

*[Pic. Capt Cook & HMS Endeavour]*

# Chapter 11: 'Three Bearing' method to find CMG

Normally CMG & SMG is found by measuring course & distance between two known positions or observed positions. But CMG direction can be found, simply by taking 3 bearings at known interval while steering a steady course. This method of finding CMG direction, does not require the help of radar, sextant or simultaneous bearings. One must remember however that this method gives CMG direction only (not the magnitude); SMG or DMG is not available. In order to find SMG or DMG, more data is required, the same is discussed in following example.

Once the CMG direction is found, one can easily determine if a cross track drift is occurring or developing. It means that one can find, whether the ship is setting landwards or seawards, without the help of radar.

## To find CMG direction by 3 bearings of same object from different positions

*Q.11.1 A ship while steering a course of 102° by compass (deviation for heading = ¾°E), observed the Romeo light as follows.*

*0400 h 157° T  0412 h 191.5° T  0428 h 238° T*

*Given variation for the area = 4 ¾° W, speed over water = 10.5 kn & current setting SW.*

*Find the position of vessel at 0400 h & rate at which current is setting. (Alpha Lt to Zulu Rds).*

**Procedure:**

Find true course of ship: Dev = ¾° E. Var = 4 ¾° W. ∴ C.Error = 4° W.

True course = 098° T.

Plot bearing lines viz. RA, RB, RC for 0400,0412 & 0428 respectively.

Draw a straight line DRE in such a way that it is clear of interfering features on the chart, clear of "Three Bearing lines' & also all three bearing lines are on the same side of DRE.

(DRE need not be perpendicular to RB)

Find the 'time elapsed ratio' or 'distance steamed ratio' between the first two & last two bearings. 'time elapsed ratio' = (0412 – 0400) : ( 0428 – 0412) = 12 : 16 = 3:4. Distance steamed ratio = 2.1M : 2.8 M = 3:4.

Cut the arcs RF = 3 cm & RG = 4 cm. (One may instead out RF = 6 cm & RG = 8 cm, but the ratio RF:RG = 3:4 should be maintained).

Through F & G draw lines *// to middle bearing* RB. These // lines meet 1st & 3rd bearing lines at H & I respectively. HI gives direction of course made good. (Length HI is not indicative of speed made good).

Through H draw HJ viz. course steered & distance steamed for 28 min i.e. 098° x 4.9M.



Through J draw a line along SW or 225° (with 3 arrows indicating current), meeting HI at K. Length HK represents distance made good in 28 min. JK represents Drift in 28 min = 0.85M. Thus hourly rate = .85 x 60/28 = 1.82 kn.

Note : Triangle HJK is a triangle for 28 min. One must ensure at this stage that

1) All the three sides of the triangle are for 28 min.
2) →→– starts from 1st bearing line.

Through K transfer first bearing line,(draw a line // to the first bearing line). Where this line meets the third bearing line is a fix at the time when 3rd bearing was taken.

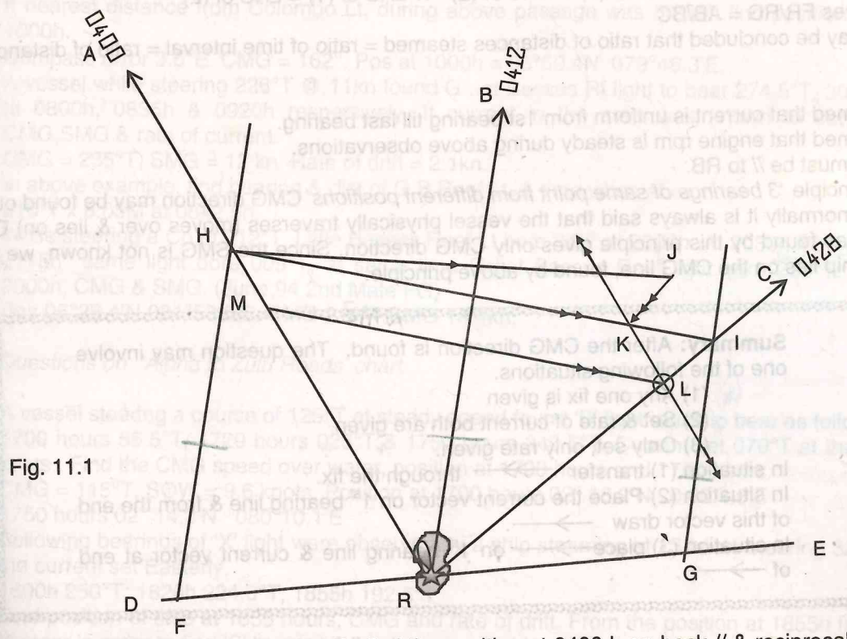



Fig. 11.1

L is actual position of the ship at 0428h. To find the position at 0400 h go back // & reciprocal to CMG till you meet the first bearing line at M.

**Ans: Position of vessel at 0400 h ≡ 02° 00.45'N 080° 13.4'E. Hourly rate of current = 1.82 kn. CMG = 106°T. SMG = 9.54 kn.**

**Principle:**

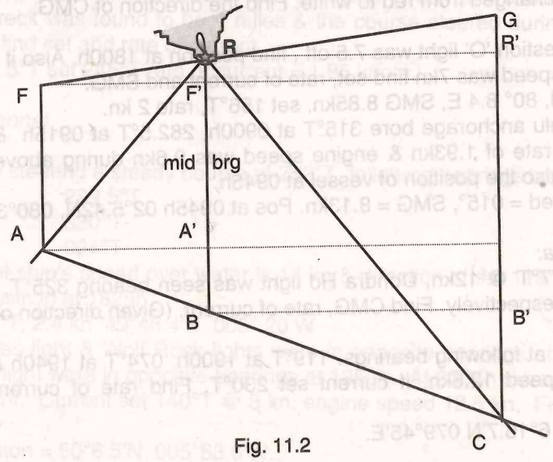



Fig. 11.2