MARINE STUDIES SERIES

CLASSROOM NAVIGATION

BOB MOFFATT

SECOND EDITION

WET PAPER

Acknowledgements

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CLASSROOM NAVIGATION

2nd Edition

by

Bob Moffatt

B.Sc. (Qld)., Dip Ed., Grad. Dip. Ed. Admin (Schools)., M.A.C.E.

Marine Education Specialist
Surfers Paradise Australia

Supported by UNESCO

Syllabus orientation

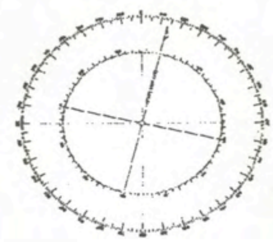
This booklet is written for the requirements of the new Senior Marine Studies Syllabus topic, Navigation. It may also be used with the Multistrand Science Syllabus topic, Science for Recreation, and the NSW and Vic other approved subject syllabus topics. Teachers of mathematics may also find it useful as an optional topic for basic geometry. It is also orientated towards the new South Pacific Marine Studies Syllabus.

Computer illustrations, bromides and photography

R. Moffatt, M. Moffatt, K. Rodgers

Technical Advice

R. Heaney



Additional illustrations

R. McAllistar, J. Green, Department of Harbours Marine

Resources required

A video on Coastal Navigation is available from:

Specialized Video Presentations
Almar Arcade
Unger St
North Mackay or
Contact the Mackay Air Sea Rescue

Charts are available from local bookshops or chandleries.
Parallel rules and compasses from boat shops.

Symbols and Abbreviations used on Admiralty Charts 5011 5th Edition 1984 Published by the Hydrographer of the Navy
Maritime Buoyage System Edition 3 1982 Published by the Hydrographer of the Navy

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OBJECTIVES

Students should be able to demonstrate competence in the following areas:

1. Knowledge: they should be able to:

1. Recall the local system of buoyage used for South Pacific waters
2. Recall common chart symbols and explain their use
3. Recall the use of the mercator projection
4. Recall the following navigation concepts or terms
   (a) latitude and longitude
   (b) nautical mile
   (c) speed, distance and time
   (d) bearing
   (e) position and fixing a position
   (f) depth soundings

2. Application of Knowledge: they should be able to:

1. Demonstrate a basic understanding of the components of a chart
2. Understand how to convert a true compass bearing to a magnetic bearing
3. Fix a position on a chart from a set of bearings
4. Apply position descriptions of latitude and longitude
5. Apply position fixing methods (e.g. three bearings, depth soundings..)
6. Solve simple problems involving distance, speed and time
7. Lay off a course between two positions on a chart
8. Maintain a log
9. Make appropriate decisions given various prevailing weather conditions

3. Practical Skills: they should be able to use specified equipment to:

1. Steer a "classroom boat" around a set course
2. Use a compass to take a bearing to within 5° accuracy on a conspicuous point
3. Use a set of parallel rules and a chart to locate position from a set of given bearings
4. Draw accurate lines from a compass rose to a bearing line to determine position using the "cocked hat method"

4. Field Excursion

1. Steer a boat on a set course
2. Take a bearing at sea to 5° accuracy
3. Use a set of parallel rules and bearings to locate position
4. Use a set of binoculars to identify common lights and local markers
5. Apply their knowledge to new situations
6. Determine tide heights using the rule of twelfths
7. Apply the boating rules
8. Apply local knowledge to sandbars etc.

5. Extension work

1. Recall the meanings of the terms *set and drift* and perform simple calculations
2. Recall the rule of twelfths and make simple calculations using it
3. Calculate the tide height for a given time at a secondary port using a tide book
4. Recall and describe some modern navigational aids
5. Recall the types of lights and lighthouses and read from a chart their specified symbols

CHAPTER 1

AN INTRODUCTION TO COASTAL NAVIGATION

A knowledge of local waters is essential for navigation

PURPOSE

To introduce you to some basic ideas about charts.

PRE-REQUISITE SKILLS

You should already have a knowledge of your local coastline.

OBJECTIVES

When you have finished this Chapter you should be able to:

* Recall some of the history of charts and Navigation
* Recall the importance of Cook as a Navigator and describe some of his voyages
* Research how your local coastline was first charted
* Identify all the features on a chart that are not represented on a map of the same area
* Draw each of these symbols in a table and suggest possible reasons for each
* Recognise key symbols such as those used for buoyage, soundings, and lights and suggest possible reasons for the inclusion of these in a chart
* Recall that charts are drawn from a variety of scales
* Recall that these details are due to the chart's importance to shipping
* Recall the definition of a chart
* Identify the following features on a chart: latitude, longitude, compass rose, date of publication, soundings, cardinal and lateral marks, magnetic variation and the amount it changes annually, and direction of current flow
* Recall the characteristics of a wave as they relate to tides
* Plot a tide for a day and a month noting the differences between each
* Explain the difference between Neap and Spring tides
* State how tides affect Navigation
* Draw a tide graph explaining the relative positions of spring, neap, mean sea level and datum
* Recall the depth at which all soundings are taken
* Recall and use the rule of twelfths to calculate the height of the tide between high and low tides for any particular day using a tide book
* Research the meaning of the concept of "set and drift"

TIME REQUIRED

8 hours

THE BIRTH OF NAVIGATION

We have been studying the oceans of the world for a long time and have added to what was recorded before. However, we owe much of our recorded knowledge to the early civilizations that inhabited the lands around the Mediterranean Sea.

The first evidence we have of scientific knowledge of the sea comes from the maps and stories which date back as far as the tenth century BC. However, long before this, voyages had been made around Africa, and Paramenides stated that the earth was round in 800BC.

Herodotus who lived about 450 BC, thought the ocean was a great ring that surrounded the world, and talked of the spherical shape of the earth.

Eratosthenes who lived about 220 BC, was the first to construct a map of the known world with lines of latitude and longitude. For example, the longitude of the pillars of Hercules and the meridian of Alexandria can be clearly seen in the recreation of his map in the figure below. Eratosthenes also called the world a sphere and was the first to calculate its approximate size with remarkable accuracy.

The Greeks thought that the sea wrapped closely around the island continent to the south where it passed beyond the Straits of Gibraltar.

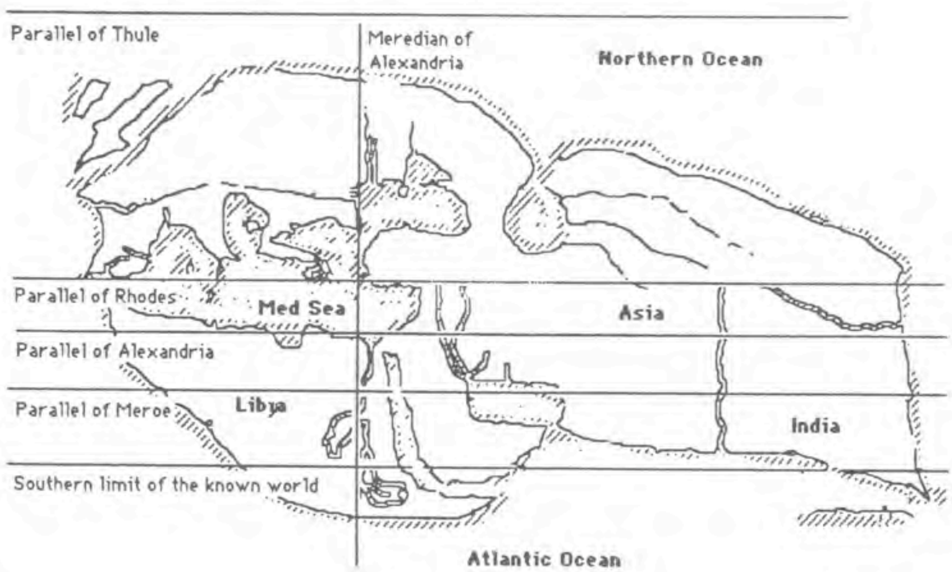


Fig 1.1: The world according to Eratosthenes.

In the second century BC a Syrian, Poseidonius recognized the moon as the cause of tides in the sea and was able to correlate the tides with the phases of the moon.

By the first century another Greek, Ptolemy made many contributions to the knowledge of the sea. His world was much larger and the world ocean was somewhat smaller. Ptolemy produced the first atlas of maps ever made. He was the first to show that the Indian Ocean was surrounded on many sides by land. His work suggested, furthermore, that it was enclosed to the south, thus confusing early European sailors who never found land south of the Indian Ocean.

With Ptolemy's death the science of Navigation went into a coma. The Romans reverted to the flat earth theory and through the dark and middle ages the science of Navigation slept.

The Vikings (AD 700-1000), made extensive ocean voyages as early records indicate, and many of their accomplishments are recorded in York, England, where actual remains of their ships have been uncovered from the soils surrounding the town. They sailed to Iceland and possibly the Americas.

In the Pacific, little is known of the origins of the Polynesians and early inhabitants of these islands. It is believed that they migrated in reed boats from the Peruvian jungles early in time and migrated to Tahiti and later Hawaii, Tonga, Fiji and New Zealand to form the Polynesian Triangle. However the actual migration is still a mystery.

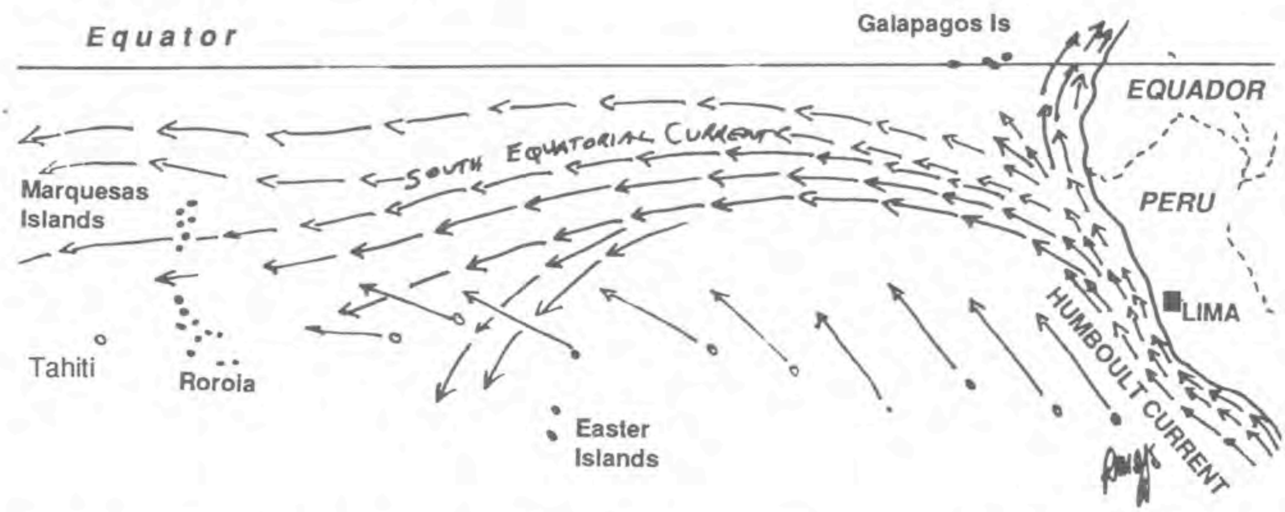


Fig 1.2: Early inhabitants of the Pacific are believed to have navigated in boats made of reeds from the Peruvian jungles.

A Spaniard, Christopher Columbus (1492) was encouraged by his King and Queen, to sail west in search of India, to bring wealth to their nation.

And so began the era of discovery which was to change the face of history. What Marco Polo was to land exploration, Christopher Columbus must be to Navigation. However he had to contend with the flat earth theory and convince enough of his fellow countrymen to sail with him.

A TIME OF DISCOVERY

Although various people sailed the world's oceans, Navigation had been restricted largely to the Mediterranean Sea.

In contrast to the detailed examination and cataloguing of species of marine animals by Aristotle, the period of discovery was marked by the expeditions of sailing ships to all of the major oceans of the world. It was a time of discovery, and the products were maps and reports of new worlds. Little attention was given to the biology of these oceans or the scientific aspects of what these explorers found.

In 1487, Bartholomew Diaz rounded the Cape of Good Hope. Then followed the four voyages of Christopher Columbus, the first in 1492 with his crossing of the Atlantic Ocean to the new world.

Other voyages of geographic importance, include Vasco da Gama's journey south around the Cape of Good Hope to India, followed by the discovery in 1513 of the Pacific Ocean by Balboa on his expedition from the Spanish settlement across the Isthmus of Panama.

Magellan in 1520 and 1521 was responsible for the first crossing of the Pacific Ocean and circumnavigation of the globe, which were completed in 1522, although he died in the Phillipines before the end of the voyage home.

He was perhaps the first to try to sound the depths of the Pacific Ocean. Using hand lines 365 metres long, he failed to reach the bottom, which was shown later to be more like 3650 m deep.

In spite of Magellan's rounding of Cape Horn, Mercator's map of the world in 1569 showed a continuous land mass from the top of North America to the Antarctic, with a narrow passage at the end of South America. In 1580, Sir Francis Drake had completed his voyage through the Drake Passage between South America and Antarctica.

JAMES COOK

Captain James Cook gathered considerable oceanographic information and claimed a number of discoveries in the years from 1768 through to 1779. Perhaps this heralded the beginning of interest in the organised study of the sea.

Cook was born in England and at 17 he was apprenticed to a corner store and clothes shop but did not enjoy the life. He felt a strong attraction for the sea and became apprenticed to a ship builder. Ten years later he joined the Royal Navy and sailed to Canada where the British defeated the French at Quebec. He married in 1762 and had six children, three of whom died during childhood.

In 1768 James Cook was given command of the naval vessel HMS Endeavour and was sent to Tahiti via Cape Horn, to observe the transit of Venus in front of the sun. Then he sailed west in an attempt to discover the Great South Land, as it was believed that there existed a great south continent which was larger than Europe. Cook sailed north and then south to discover New Zealand. He circumnavigated and charted these islands and proved that they were not part of the South Continent.

The Endeavour then set sail for the unknown continent, which the Dutch had called New Holland, and which was later to become known as Australia. Cook sighted the coast of what is now Victoria on April 19, 1770. Finding no place to land he continued northward along the coast until on 28 April 1770 he finally went ashore at Botany Bay, just south of where Sydney now stands.

Cook continued North naming many features on the eastern Australian coastline. He encountered the Great Barrier Reef with disastrous results when his vessel holed in coral just east of where Cooktown now stands. The vessel was floated off with the tide and beached in the Endeavour River for repairs.

Fig 1.3: Captain Cook was responsible for charting many South Pacific Islands.

When Cook reached Possession Island near Cape York he claimed the eastern seaboard for the British Crown, and this he named New South Wales. The Endeavour then sailed back to England, first stopping at Jakarta, then round the Cape of Good Hope to arrive back in July 1771.

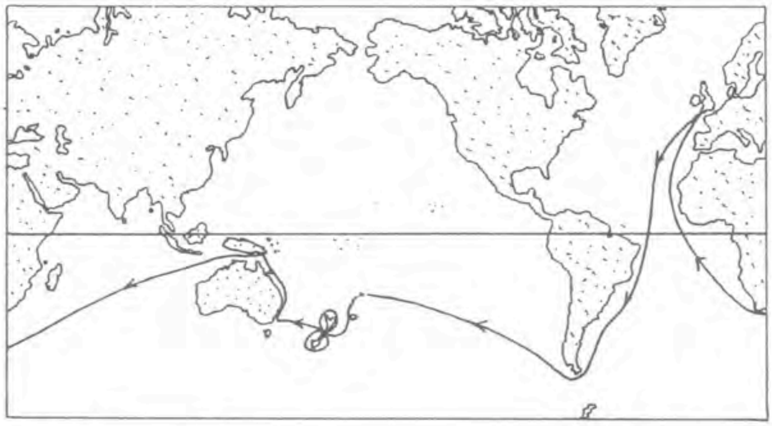


Fig 1.4: Cook's first vovage

Second voyage

Cook's second voyage, from 1772 to 1775, was with two ships, *the Resolution* and *the Adventure*. This was the voyage on which he crossed the Antarctic Circle and circumnavigated the South Pole.

He spent the months of the short summer exploring Antarctic waters in search of the southern continent. The winter months he spent either in New Zealand or criss-crossing the Pacific to Tahiti. It was after his second season in Antarctica where he reached a latitude of 71°10'S that he undertook his tremendous cruise to Easter Island, the Marquesas, the Society Islands, the Friendly Islands, the New Hebrides, New Caledonia and Norfolk Island, returning to New Zealand.

Then, in November 1774 Cook set a course from New Zealand for Cape Horn. He rounded South America south of Tera del Fuego, called in at South Georgia, which he claimed for Britain, discovered and named the South Sandwich Islands, and sailed on to the Cape of Good Hope.

Finally after three years and eighteen days at sea he reached England.

Adventure made her own way home after losing contact with Cook in a gale off New Zealand prior to *Resolution's* second season in Antarctica.

Cook proved that the Great South Land was indeed a myth.

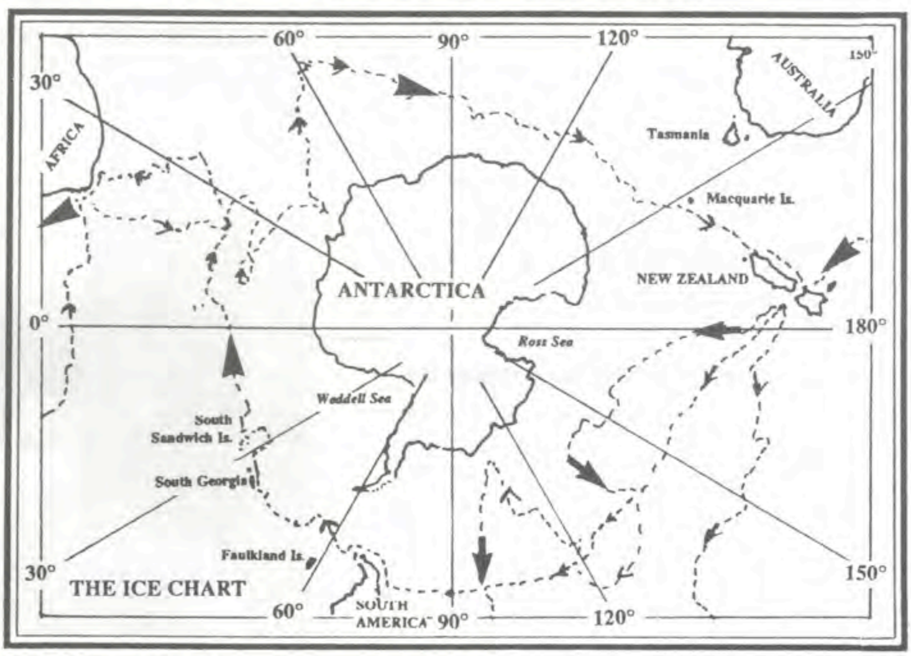


Fig 1.5 Part of Cook's second voyage (after Blackman, H.J.)

The final voyage

Cook's final voyage began in 1776. He was sent by the King to find a passage across the top of Canada. To do this, he sailed around the Cape of Good Hope to New Zealand, then north to Tahiti and Hawaii. He then made for California and sailed up past Alaska and into the ice pack of the Arctic Circle. After turning into the Bearing Strait he spent ten months attempting to find the infamous North West Passage. He reached a point 70°44' North.

After ten months, he gave up in despair and returned to the Hawaiian Islands where, during an attempt to solve a dispute with the Hawaiian people, he was killed in 1779. His first mate tried again to find the North West Passage but failed. John Gore then took the two ships, the *Resolution* and the *Discovery* back to England in 1780.

Cook charted the oceans as no man had done before and laid the foundation stone from which Navigators could find their bearings and take their measurements. He proved that you could stay at sea for a long time without catching scurvy. He discovered that if limes were eaten, this reduced the chance of infection and recorded for the first time, surfing in Hawaii. Cook was possibly the world's finest navigator.

STUDY ASSIGNMENTS

1. Find out about Kay Cottee, the first lady to single-handedly circumnavigate the earth. If you write to:- *The Editor, Sistership, PO Box 1027, Crows Nest, NSW. 2065*., you can buy a copy of an account of her history making voyage.
2. When were South Pacific islands first inhabited? Write a series of short paragraphs on the discovery of your island.
3. In the Pacific, many different cultures came from many different islands or groups of islands. How did these early navigators know where to go? What instruments did they use?
4. What methods of navigation are used by tribal leaders today? Have they changed and if so, how?
5. Are the stars still used to navigate in South Pacific Island villages or in the Torres Strait Islands?
6. What other methods of navigation are used?
7. Look at Fig 1.6 taken from the Fiji museum. These parts of ancient canoes were used by early South Pacific peoples to navigate to new lands.
   (a) Find out what they are and how they were used.
   (b) How big are they and what would they weigh?
   (c) To what types of boats were they attached?
   (d) How many people could fit into these boats at once?
   (e) How did they provide for themselves on long journeys?

Fig 1.6: What are these and how did they help early South Pacific Navigators steer their boats?

LOCAL CHART FEATURES

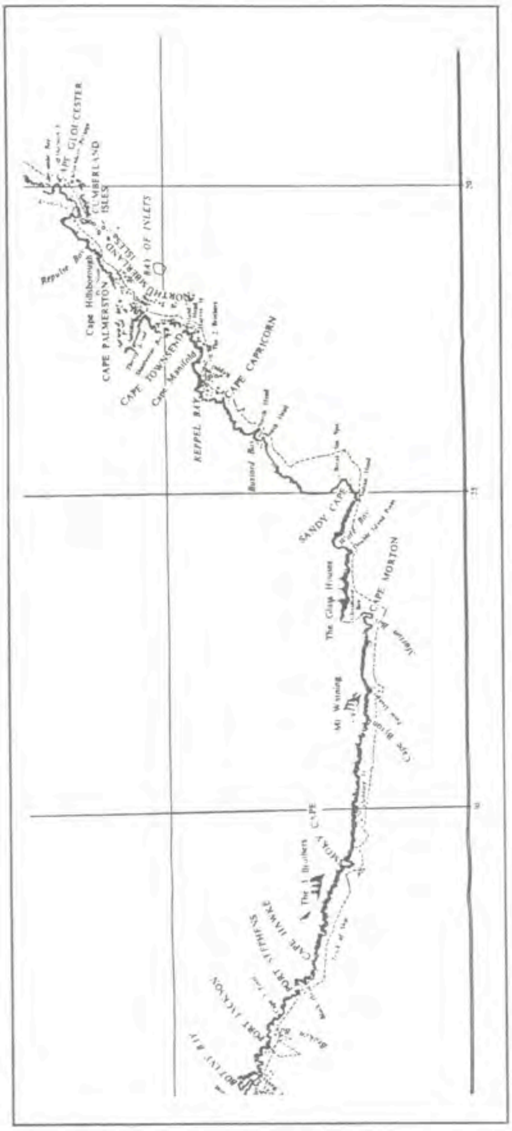


Fig 1.7: Part of Cook's original chart made in 1770 showing parts of New South Wales and Queensland

The South Pacific's coastline is varied. There are volcanic sea mounts and coral crusted reefs. There can be weeks at sea when no land is sighted, but when a landfall is made, knowledge of the local coastline and an interpretation from a chart is vital for the safety of a ship.

Modern navigation charts are needed for ships that visit our waters bringing tourists, as well as cargo ships delivering food and equipment. Most of you would be familiar with one part of the coastline, but if you went somewhere else, would you be able to navigate safely without a chart or someone who had local knowledge?

How much do you know about what lies beneath the waters nearest your school? Just imagine the difficulties your ancestors must have had in learning about these new lands. Many of the charts we use today were drawn by some of our earliest navigators. In fact some of *Captain Cook's* charts are still in use today.

As you progress through this course you may have a chance to go to sea to experience some of the difficulties in working there. Hopefully you will admire some of the skills and determination of the seafarers who laid the foundations for these great nations.

How do mariners navigate the world's waters, be they open sea or inshore? What equipment do they use and how do they learn to select the most appropriate type? Let's find out now.

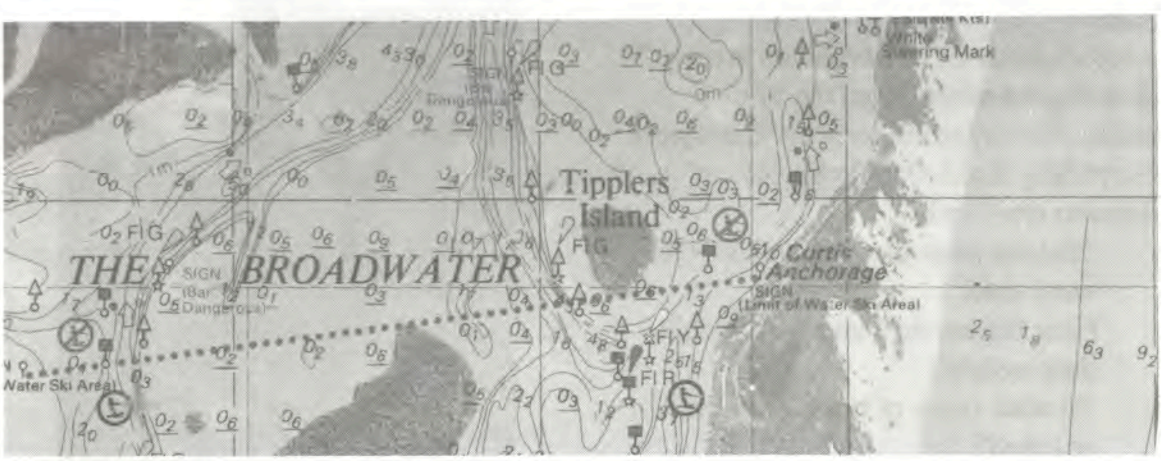
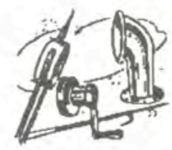


Fig 1.8: Part of a local chart made today. This is a large scaled chart compared to a small scaled chart shown over. Reproduced courtesy of the Queensland Department Harbours Marine.

In the first activity you will need a chart of your local harbour.



Charts are available in various scaled sizes and are either:

(a) large scale which shows a lot of detail over a small area (e.g: your local harbour)
(b) medium scale which shows slightly less detail over a larger charted area (eg: your local coastline)
(c) small scale which shows little detail over a much larger charted area (eg: your State's coastline).

In this map of Australia, we can see that there are a number of areas marked out. These are the small scaled charts which will show a large area. They are not much good for local conditions and should not be used for Activity 1. Their main use is in large ocean voyages for calculations of positions.

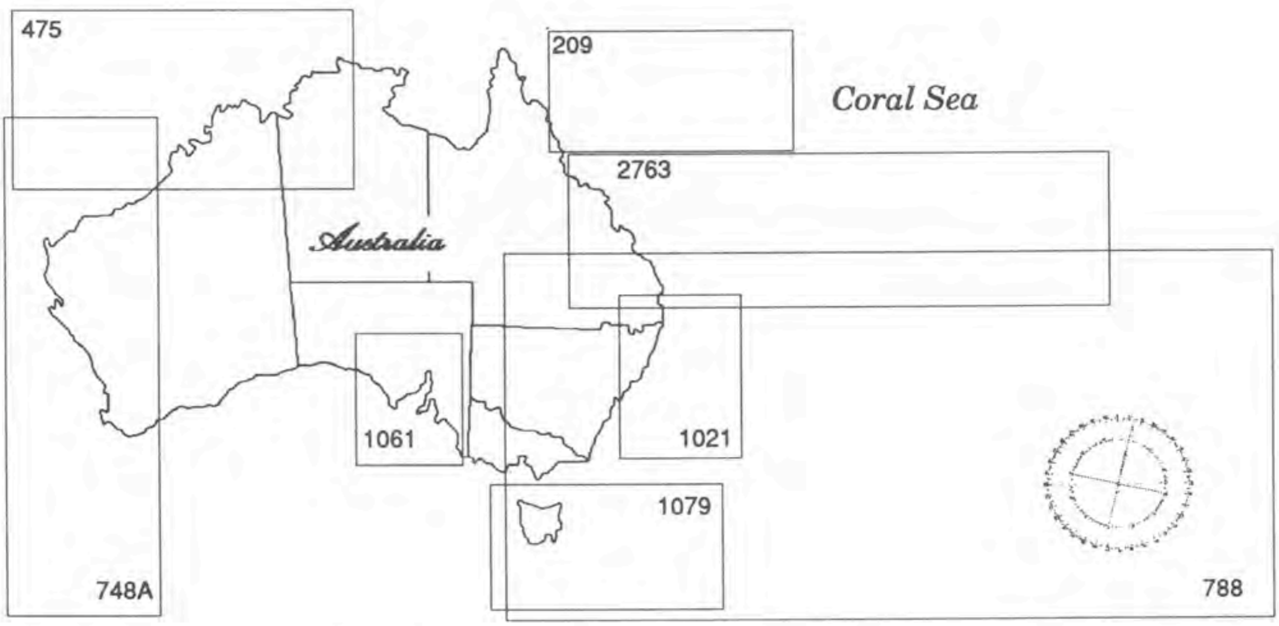


Fig 1.9: Small scaled charts are used for large areas of water. Chart numbers are approximate only and for full details consult the chart catalogue at your local chandlery.

You will need a chart of your local area. Where do you think you could buy such a chart?

CHARTS

***A chart** is a curved section of the earth's surface reproduced on a flat piece of paper.*

***A map** is a representation of the earth's surface on a plain surface.*

Essentially there is no difference between the two except that one is used for Navigation. There are obvious difficulties in making a curved surface flat. Try flattening half a tennis ball without splitting it. You can understand that a number of problems will arise when we try to make a chart.

There will be some distortion somewhere, and yet if a chart is to be of any use, it must be flat and have a high degree of accuracy.

In the case of ***Mercator charts,*** the charts most commonly used for ships of all kinds, the major distortion will be at the extremities of the earth - ***the poles***.

However since most ships do not navigate these waters, the problems are reduced. In the more temperate and tropical zones, where most navigation is carried out, the distortion is relatively slight, and at the Equator it hardly exists.

The Mercator system by which naval charts are made is best understood if we imagine the world as a plastic globe with a light in the centre and a flat wall opposite.

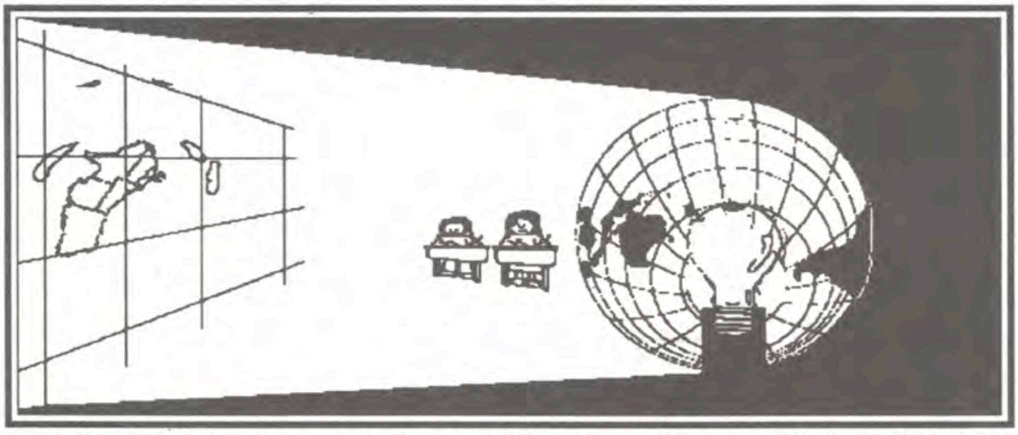


Fig: 1.10: The principle of chart making could be thought of in terms of the image that would be formed on a wall from a bulb shining inside a world globe.

When the light is switched on the contours of the land masses will be thrown on to the wall in the form of a flat plane. At the centre (the Equator), there will be little distortion, but near the ceiling or floor level considerable distortion will occur.

ACTIVITY 1.1: YOUR LOCAL CHART

Aims:

At the end of this activity you should be able to:

(a) Identify all the features marked on a chart, that are not represented on a map of the same area.
(b) Draw each of these symbols in a table and suggest possible reasons for them.
(c) Recognise key symbols such as those used for buoyage, soundings and lights and suggest possible reasons for the inclusion of these in the chart of the local area.

You will need:

* A chart of the local area (Available from Harbours & Marine)
* A map of the local area
* Worksheet 1 from the copyright-free appendixed page 86

Fig 1.11: A group of students navigating local inshore waters.

What to do:

Look carefully at the map and then at the chart and write up a list of 10 differences between the chart and the map on the worksheet. Record these in a data table on Worksheet 1 giving your reasons for the differences.

Now answer the following questions in the spaces provided on the worksheet

1. What is the deepest section of water on the chart?
2. What is the most northerly point on the chart?
3. Why does a chart need latitude and longitude?
4. What date was the chart prepared?
5. Is there a scale on the chart and, if so, what scale is used?
6. What are the main shipping lights nearest the local port?
7. What is the main degree of latitude and longitude ?
8. Is the chart in fathoms or metres?
9. Draw each symbol in the table provided on your chart and beside it write its purpose.
10. If you had to navigate a ship into port, why would you use a chart rather than a map?

Because only a small portion of the earth's surface is reproduced on most charts, only a small distortion will occur. In the higher latitudes, those nearest the equator, this is not noticeable and lines of latitude and longitude appear on a chart as straight lines. A nautical chart used for marine navigation shows land outlines, prominent land features (natural and those made by humans), depth of water, channels, navigation markers and a compass rose. Why? Because these are the features navigators need.

You should have noticed the soundings on the chart. These indicate how deep the water is at a particular place. But how does this change with tides and what is the effect? The next section looks at this.

TIDES

Tides *are the periodic rise and fall of the water on the earth's surface.* But really does the water rise and fall? Tides are actually one big wave caused primarily by the moon.

The earth spins into this wave and causes the water at the edge of continents to rise and fall on a regular basis. Australia and the islands of the Pacific are moving east into a large standing wave. This gravitational attraction causes the water in the Pacific to bulge up at one side. The nett result is a high tide on one side and a low on the other.

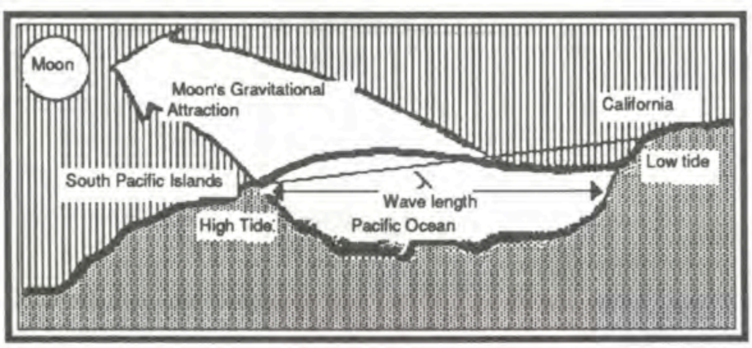


Fig 1.12: The moon's gravitational attraction causes daily tides.

The tops of waves are called crests and between these are the troughs. The height of the wave is represented by (h) and the distance between crests is called the wavelength.

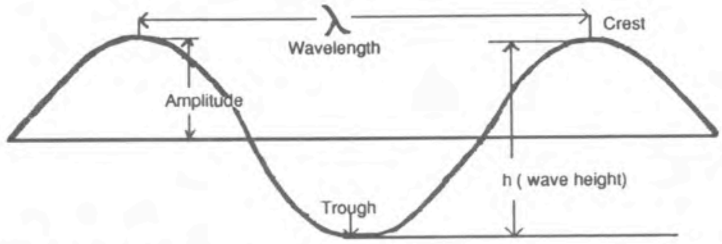


Fig 1.13: General features of a wave in the ocean

But how fast does the earth spin? We know that one revolution is 24 hours and we know that the tides occur approximately every 6 hours. Therefore, there must be four tides a day and four standing waves that any place in the South Pacific moves through. The photograph below shows a vessel stranded by the tide. Why is it important to know the tide times and heights?

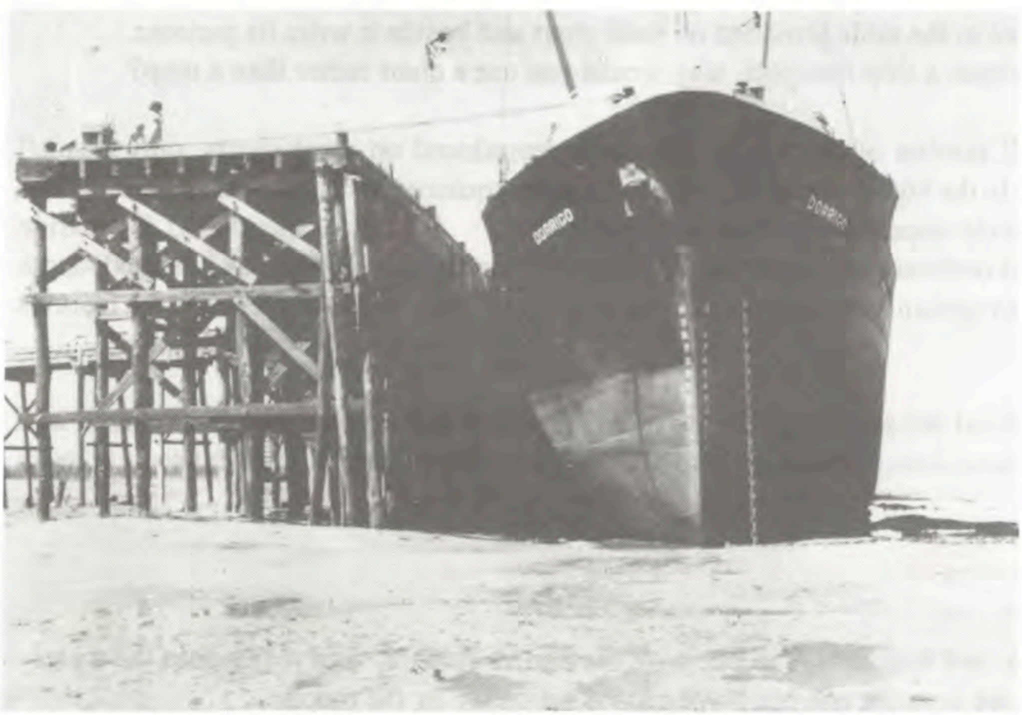


Fig 1.14: The tide at Derby in Western Australia is over 10 metres. Photograph by Allan Nicholls.

ACTIVITY 1.2 DAILY TIDES

Each day there are two high and two low tides.

Part A: Collecting data

You will need

1. A sheet of graph paper
2. Copy of a tide book page (page 95)
3. Your teacher's help if you have forgotten how to plot graphs

What to do

Plot the tides for any chosen day. Use half the sheet of graph paper to do this and make the *x axis time* and the *y axis height*..

Make sure you work out the ranges for each scale and if you are unsure, ask your teacher to help you with the scales.

Questions to answer

How many tides are there in a day? Is the tide height the same for each? Is one high tide higher than the other for the day?

DAILY TIDES

The distance between high and low water over a tide is called the tidal range. Figure 1.17 over shows this difference. Look at figure 1.14. This tidal range is over 10 metres and occurs twice a day.

Daily tides are caused by the position of the moon and the rotation of the earth. There are 5 hours and 54 minutes between tides. Study the results you obtained in your graphing experiment. You should have concluded that each height was different. This difference in height occurs because the earth spins through two different heights of tide. One height is higher because the point above the tide is directly below the moon. The other height is caused by the earth's centrifugal force and is slightly lower. Also tides in the summer are higher during the day due to the position of the earth in its orbit around the sun.

In fact there are over 52 variables that control the tides. It is beyond the scope of this book to discuss all, however we are going to consider three more. That is the relative positions of the sun, earth and moon.

SPRING AND NEAP TIDES

Tides also vary over the month. The next activity is designed to show you these changes.

ACTIVITY 1.3 TIDES OVER THE MONTH

You will need

1. A sheet of graph paper
2. A sheet for the tides (page 95)

What to do

1. Select a port which shows the tides over a month.
2. Study the tides and plot these on a sheet of graph paper using appropriate scales.

Fig 1.15: You can only walk out to the reef's edge at low tide. The lower the tide, the more coral is exposed.

Questions to answer

1. Mark on the graph the spring tides and the neap tides.
2. What dates are the spring tides and how high are they?
3. How often does the cycle change?

You should have noticed a change in tide heights over the month.

The high points in the graph are the spring tides and the low points, the neap tides.

These can be explained by considering the relative positions of sun, moon and earth as outlined below.

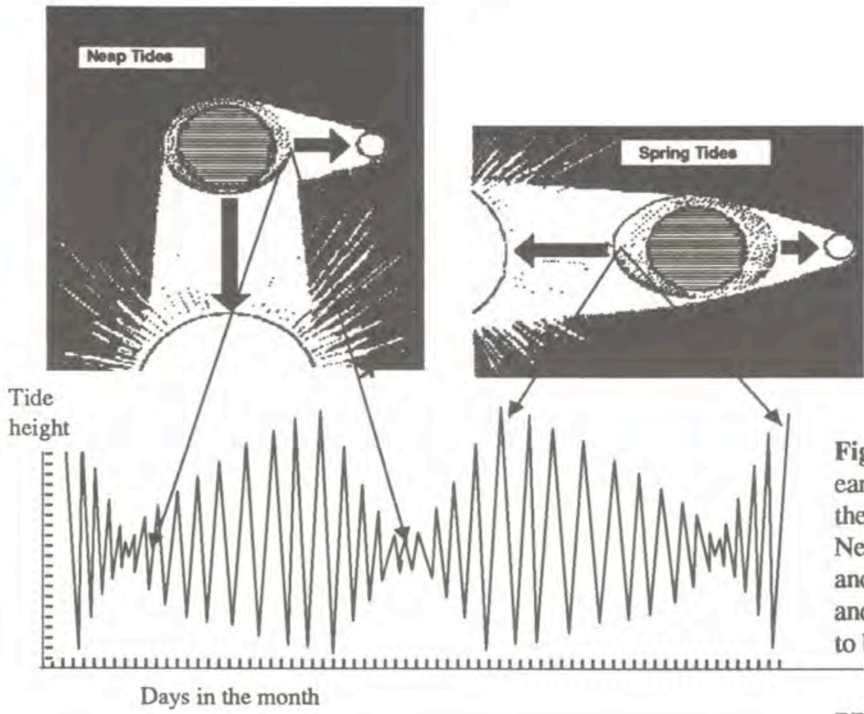
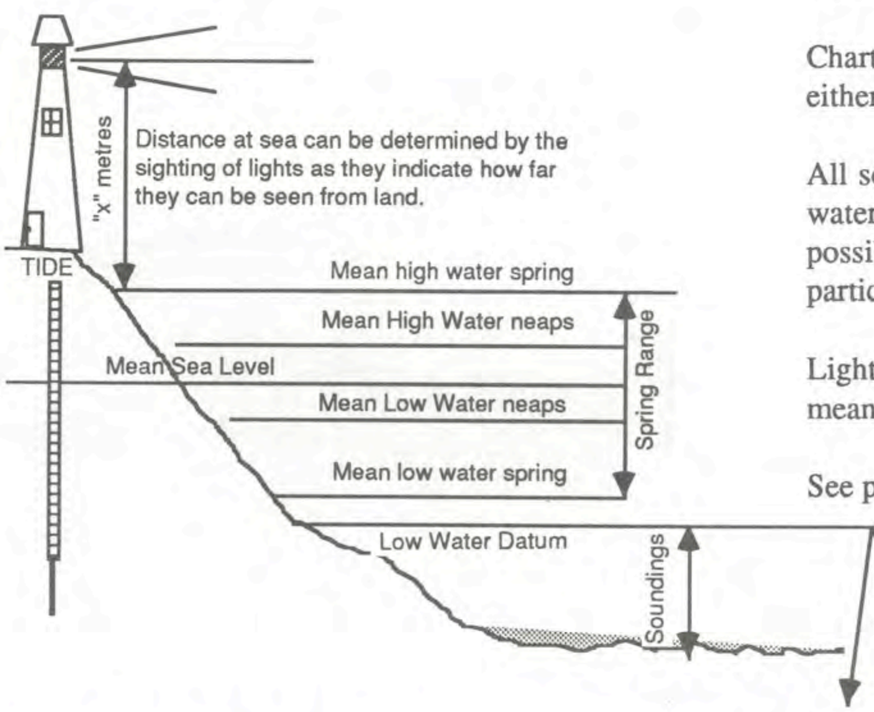


Fig 1.16 Spring tides occur when the earth, moon and sun are in line, causing the greatest gravitational attraction. Neap tides occur when the sun, moon and earth are positioned at right angles, and the gravitational attraction tends to be in opposition.



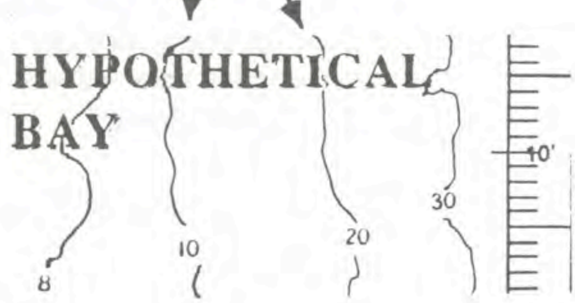


Fig 1.17: Mean Low Water Spring is the sounding on a chart. The tide has to be added to give the height of water under your vessel.

So when navigating coastal waters, always take into consideration the tide and calculate the amount of water that is under your boat.

HOW TIDES AFFECT NAVIGATORS

Chart soundings are marked in either fathoms or metres.

All soundings are taken at a low water datum which is the lowest possible level water can fall for a particular area.

Lights are marked in metres above mean high water spring.

See page 96 for more details.

FINDING THE HEIGHT BETWEEN THE TIDES

How can you find out the amount of water under a vessel at any one time? Mariners use the ***RULE OF TWELFTHS.***

Using the tide tables listed consider May 1st. *WHAT IS THE TIDE HEIGHT AT 9am ?*

How much water will be under my boat at 9am on Sunday May 1st?

1	0502	5.2 (High tide first thing in the morning)
	0900	???
Sun	1137	0.8 (Low tide about 6 hours later)
	1752	4.9 (Second high tide for the day, again about six hours later but lower than the morning tide)
	2349	1.2 (Second low tide late in the night)

The Rule of Twelfths states that:-

at nearly all places, the tide rises or falls by the following approximate amounts each hour:

First hour	-	1/12th of range
Second hour	-	2/12ths of range
Third hour	-	3/12ths of range
Fourth hour	-	3/12ths of range
Fifth hour	-	2/12ths of range
Sixth hour	-	1/12th of range

WORKING

First calculate the tidal range for the day.

In our case we see that the tide ranges from 5.2 to 0.8, so by subtracting, that gives a 4.4m tidal range.

TIDAL RANGE

  5.2 m
- 0.8 m
  4.4 metres

Second, use the rule of twelfths:

So to find the tide height at 0900 hrs we calculate as follows:

* The tidal range is 4.4 metres
* 0900 hrs is 4 hours after high tide
* From the rule above, the total drop in the tide will be as follows:

First hour -	1/12 th of 4.4 is	0.37 m
Second hour -	2/12ths of 4.4 is	0.74 m
Third hour -	3/12ths of 4.4 is	1.11 m
Fourth hour -	3/12ths of 4.4 is	+ 1.11 m
Total drop in tide over 4 hours is		3.3 metres

*So the tide height at 9 am will be 5.2 m
- 3.3 m

Answer  1.9 metres

Now what exactly have we worked out?

We have worked out that at 9am on the 1st May, the water will be 1.9 metres deeper than stated on the chart for that area. E.g: if the chart says the water depth in a certain channel is 2.0 metres, then the depth will actually be 2.0 + 1.9 metres = 3.9 metres deep in that channel at 9.00am May 1st.

THE DIRECTION OF THE TIDAL CURRENT

The direction of the tidal stream is also important. This can easily be observed by:

(a) Boats at anchor riding head on into the stream
(b) Buoys leaning away from it
(c) Water swirling around a post or covered object

Tidal streams also appear to flow the fastest in deep waters, off headlands or in navigation channels or during the third or fourth hour of an ebb or flood tide.

FOR FURTHER RESEARCH

Find out what the terms *set and drift* mean. How important are they and of what significance are they to navigators? How do tides occur? What is the difference between spring and neap tides and how do they affect navigation?

Questions

1. Give the 24 hour clock time for the following:
(a) 6 am (b) 6 pm (c) 4 pm (d) 3.30 pm (e) 10.30 pm

2. Convert the following times to regular clock times
(a) 0230 (b) 1545 (c) 1730 (d) 2312

3. Using the table of tide heights on page 95, find high tide heights for May 2nd

Answers: 1. (a) 0600 (b) 1800 (c) 1600 (d) 1530 (e) 2230 2. (a) 2.30 am (b) 3.45 pm (c) 5.30 pm (d) 11.12 pm 3. 0601 - 5.2 m 1841 - 4.2m 4. Sun 1/5 11.49 pm

SUMMARY

Let's summarise by answering this question, "What will be the tide height at the boat ramp at 9am Tuesday?"

3	0045	0.9
	0656	5.1
Tu	**0900**	**?**
	1307	0.6
	1935	5.6

Firstly work out the tidal range in between the tides in question : 5.1 - 0.6 = 4.5m.

Secondly work out how many hours after the tide in question you want the tide height: 2hrs.

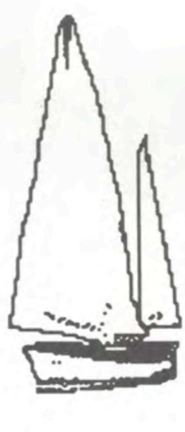
Thirdly apply the rule as many times as need be and add up the fall or rise in height: 1.1.

Finally subtract or add as the case may be 5.1 - 1.1 = 4.0 .

Did you get 4.5m for the range, two hours for the time difference, 1.1 for the fall, and 4.0m for the height at the ramp?

CHAPTER 2

NAVIGATION INSTRUMENTS



PURPOSE

To introduce some basic navigation instruments so that you can learn to use them with skill and accuracy.

PRE-REQUISITE SKILLS

A knowledge of the compass points, a good eyesight and basic mathematics of multiplication, division, addition and subtraction.

OBJECTIVES

You should be able to:

* Recall the four major inventions which made modern navigation possible
* Define the term Navigation
* Recall the three important modern day navigation instruments
* Distinguish between the use of a master compass and a handbearing compass
* Recall the use of a chronometer, a log and how each is used
* Recall the Symbols for the Cardinal and Lateral systems of buoyage
* Recognise the above symbols in the tide book
* Recall the safety rules for boating
* Recall important international Code Flag Signals
* Interpret the rules and regulations as set out in the tide book
* Plot a safe course into and out of a harbour
* Construct a compass rose and label the traditional cardinal points
* Use a handbearing compass to take 6 accurate bearings.
  (To the accuracy of the instrument used)
* Construct a simple compass from sticks, an orienteering compass, and cardboard
* Calculate distance, speed and time for the two legs of the set course

TIME REQUIRED

4 hours

Fig 2.1: A handbearing compass and a set of parallel rules are some navigation instruments that are used in classroom navigation. Storage is made easier if trays are made for the parallel rules and boxes with foam cut-outs for compasses.

EARLY NAVIGATORS

According to our best estimates we have been navigating the sea for at least 6000 years.

As we saw in Chapter 1, most impressive were the Polynesians, who crossed thousands of miles of open ocean in the Pacific, to discover Hawaii using charts of reeds as early as 1500 B.C.

Scientists and mathematicians of that time worked out a method to find both latitude and longitude accurately. Why are latitude and longitude important? Vessels were made to travel longer at sea. They could carry men and provisions for months at a time.

Three people who made outstanding inventions which contributed to the success of ocean voyages were John Napier who invented logarithms in 1614, Edmund Halley, who invented a quadrant in 1731, and James Harrison, who perfected the chronometer between 1735 and 1761.

About 1757, *the sextant* was developed which enabled mariners to take accurate bearings at sea but nobody seems to know for sure who invented it.

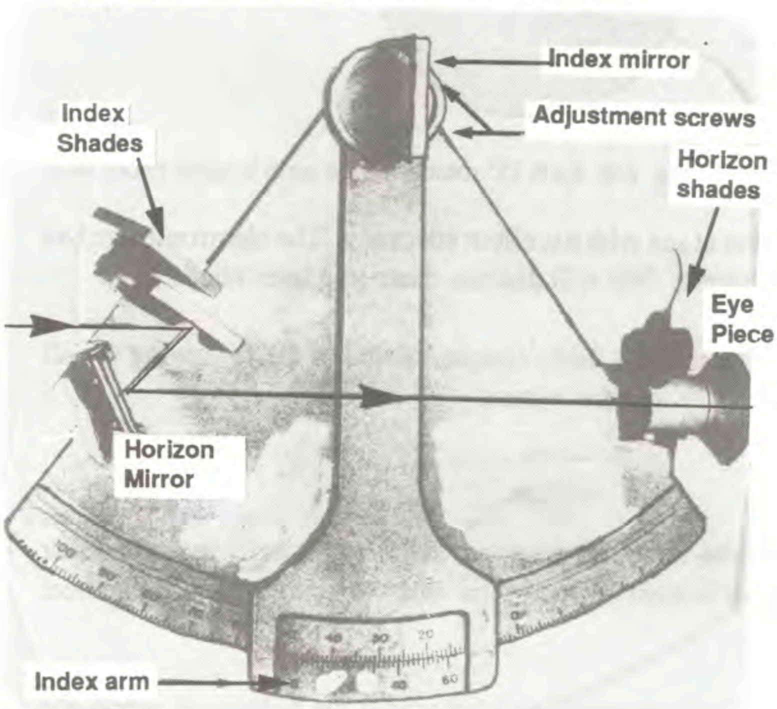


Fig 2.2: A sextant

NAVIGATION

Today an experienced navigator, people who fish, or sailors, can negotiate coastal inshore waters with little other than local knowledge, but for longer voyages the mariner needs mathematics and astronomy.

But what is Navigation? The word navigate comes from the Latin *"navigere"* meaning navis (ship) and *agere* (move or to direct).

Marine ***navigation*** may be simply defined as:

"The art of directing a vessel at sea".

SOME NAVIGATION INSTRUMENTS

Among the most modern instruments developed for navigation of the sea are the *compass, chronometer* and the *sextant.*

We do not know who invented the magnetic compass. It is one of the oldest instruments and it is thought to have originated in China with the discovery of a naturally occurring magnetic material called *lodestone.*

The chronometer

This instrument is an extremely accurate clock, and its invention, used to determine longitude, helped early mariners explore the world.

If the earth is viewed from above the pole, the chronometer rotates through 15 degrees each hour (24 x 15 = 360°). Therefore each 15 degrees of east or west travel on earth represents one hour's difference.

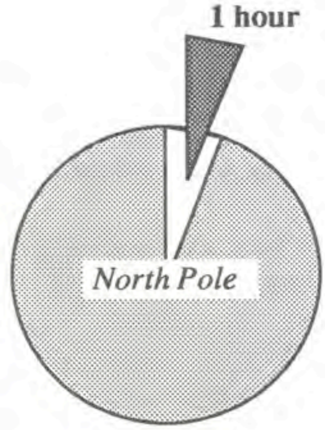


Fig 2.3: Each 15° rotation of the earth is equal to one hour

The sextant

This enabled the mariner to determine location at sea with excellent accuracy. The electronic age has added radar, loran and echo sounding equipment. We will discuss these in a later chapter.

Besides electronic gear, most navigation equipment is fairly simple. Some of the following are all that is required to navigate most small craft over inshore waters.

The master compass

This compass is perhaps better described as the 'steering' compass since it is usually mounted near the driver's seat. It is mounted in a gymbal or it must be one of the 'free swinging' types so that heel and roll of the ship do not affect it.

A 'lubber line' indicating the ship's head is clearly marked, against which the helmsman steers the required course. A light is usually fitted so that the card can be illuminated at night. A lubber line is shown below on the handbearing compass.

The master compass can be mounted in a number of different ways to suit its location, bearing in mind the effect of outside magnetic fields which may induce errors into the reading.

Before any boat sets out on an extended voyage, the compass must be 'swung' to determine and correct errors caused by boat construction. (See Page 97 for compass deviation corrections.)

Fig 2.4: The master compass

The Hand Bearing Compass

The master compass is usually a fixture near the steering position; the handbearing compass is free and can be carried to the most suitable spot on the boat for navigational observations. It is the navigating compass.

For this reason, the hand bearing compass is usually much smaller and lighter and incorporates some form of sighting device, the simplest and most common being the 'V' sight used on small rifles.

Because it is relatively small, this type of compass usually has a magnifying glass to enlarge the figures on the card.

It may also have a mirror which enables the card to be read while holding the compass at eye level while you look through the 'V' sight.

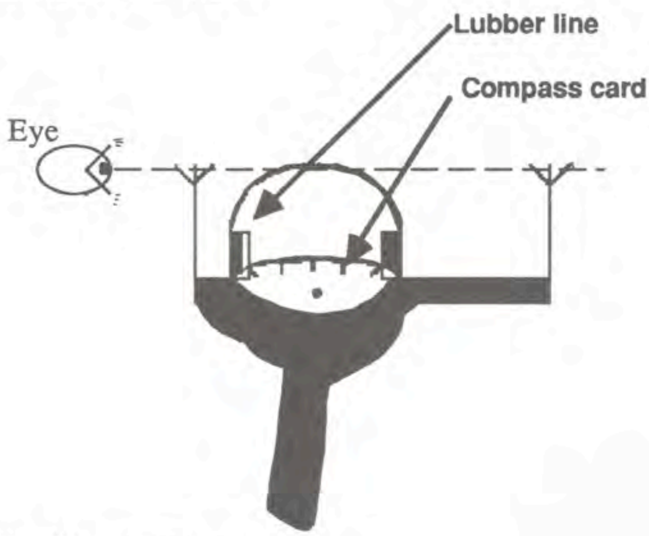


Fig 2.5: Parts of the handbearing compass

The Chronometer

The precision chronometer of times past is no longer as essential as it once was when ships had no contact with the shore for weeks, sometimes months, on end. Radio enables ships even in the middle of the bigger oceans to remain in touch with civilisation at all times.

Nowadays, radio time signals, broadcast every second for twenty-four hours a day from strategic points around the globe, enable any vessel to get an accurate observatory time check at any time of day or night, anywhere in the world.

Thus, a good quality wristwatch (with sweep second hand) will suffice. Checking a watch daily with a radio time signal and keeping a 'rate' check - the amount the watch gains or loses each day - should provide sufficient accuracy for our purposes.

Fig 2.6: Ships chronometer

ACTIVITY 2.1: MAKING A COMPASS ROSE

Aims:

At the end of this activity you should be able to:

* Construct a compass rose and label the traditional cardinal points.

* Use a handbearing compass to take 6 accurate bearings (to the accuracy of the instrument used).

You will need:

* A handbearing compass or materials to make a simple one (see Fig 2.7)

* A protractor, paper and pencil

* Worksheet 2 (Copy Page 86)

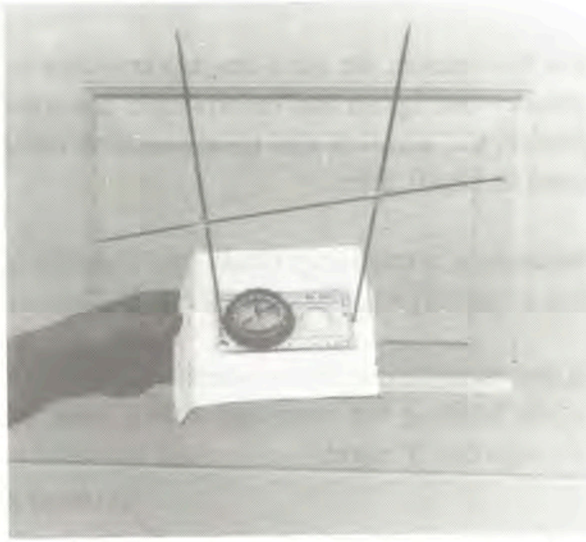


Fig 2.7: A simple handbearing compass can be made by using a cardboard base, two satay sticks and an inexpensive orienteering compass

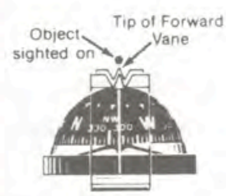


Fig 2.8: The correct method to sight a bearing using a rifle sight handbearing compass

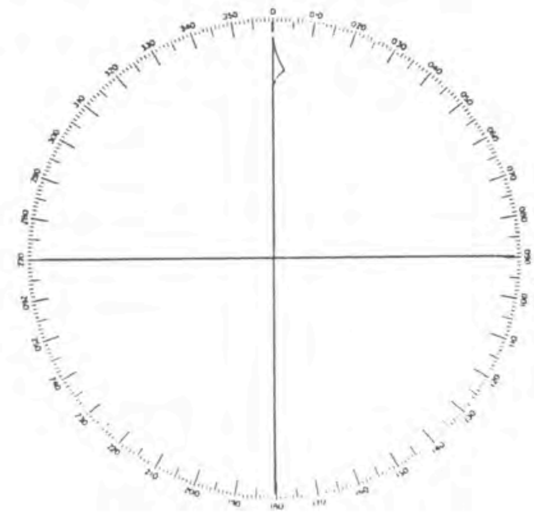
What to do:

(Note: Part C could be a class activity or completed by a group while other class members do Parts A and B)

Part A: The Traditional Compass Rose with its Cardinal Points

1. Starting at the top of the circle, mark in 0° to indicate North, and then 10°, 20°, 30° ....360° around the compass.

2. On the inside of the circle mark off the compass points *N, NE, E, SE, S, SW, W, NW*.



Part B: Taking a Bearing

Complete the data table by taking 6 bearings from various locations around your school or classroom.

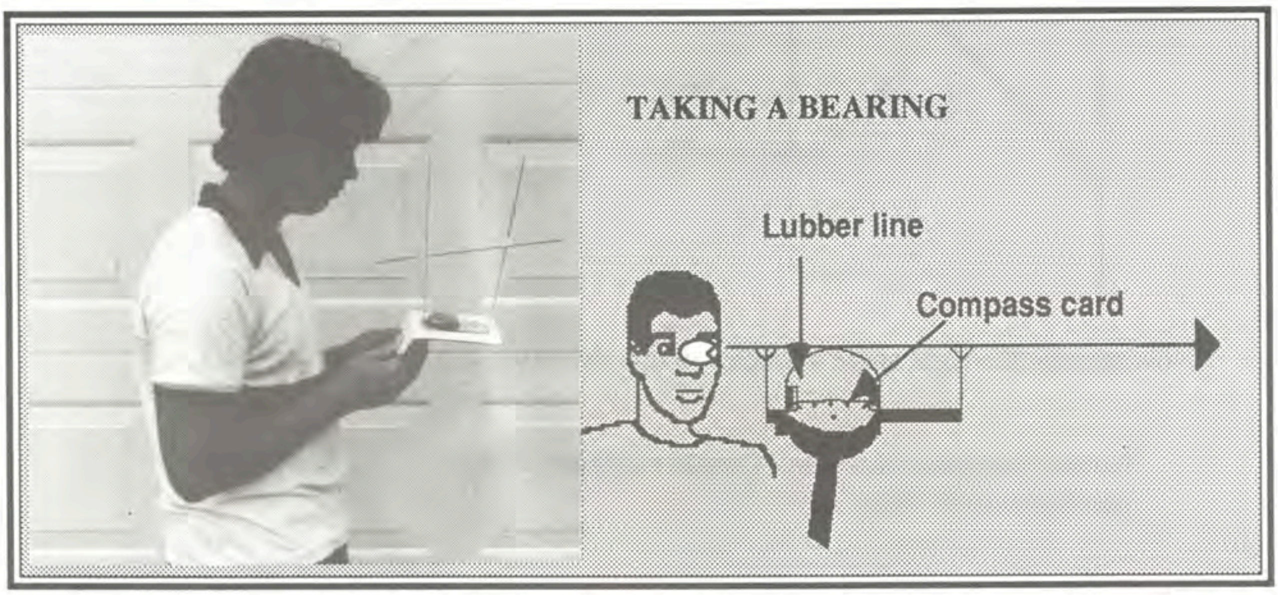


Fig 2.9: If you make a simple handbearing compass, hold it as shown in the photo and look through your sticks to line up the object, then rotate the compass top and look down to read the bearing off the card

Compare your answers with others in your class. Did they all get the same bearing? Why or why not?

Bearing from	Bearing to	Bearing °
	SAMPLE ONLY	

ACTIVITY 2.2: USING PARALLEL RULES AND THE COMPASS ROSE

Aims:

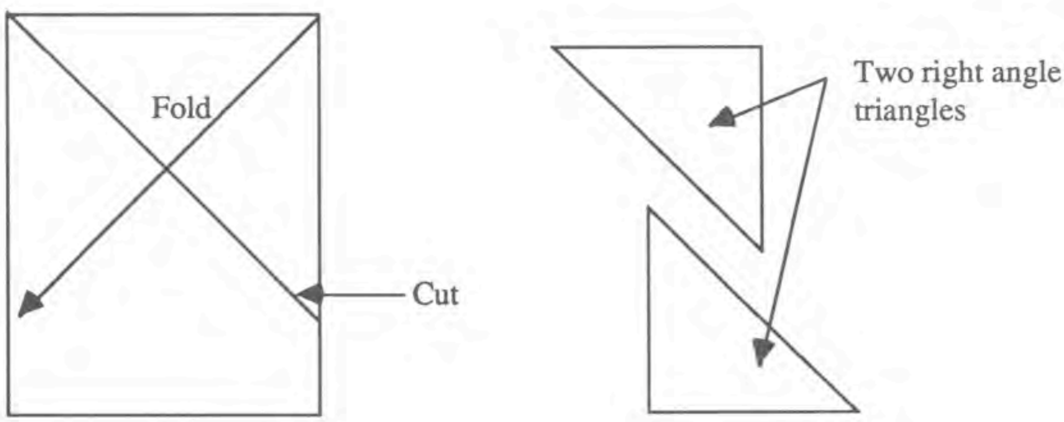
* To use a set of parallel rules to determine bearings from a number of points on a chart
* To convert to and from true and magnetic bearings

You will need

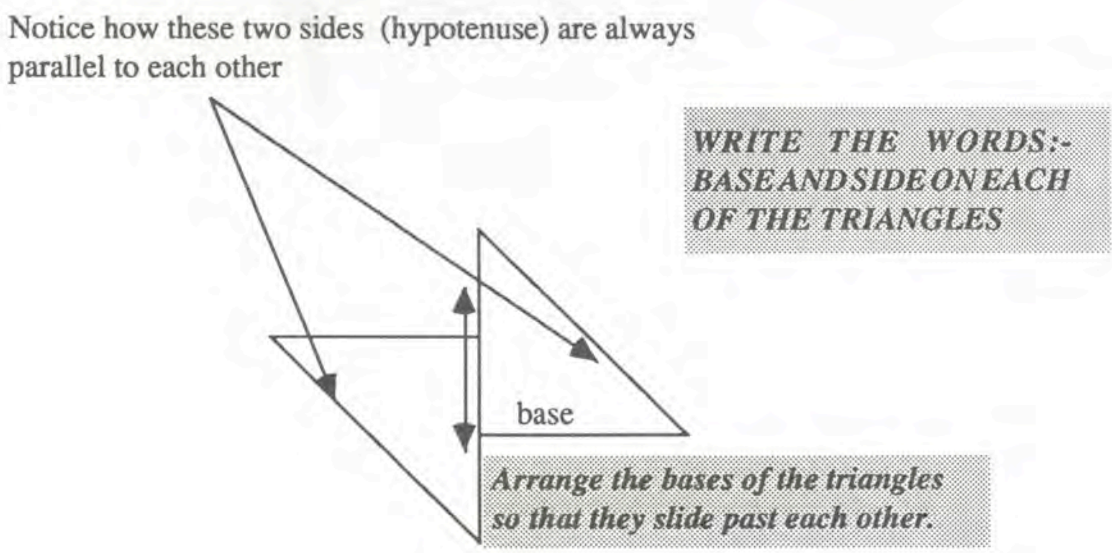
* Half a piece of coloured paper
* Pair of scissors
* A set of parallel rules or equivalent
* Worksheets 2 and 3

What to do

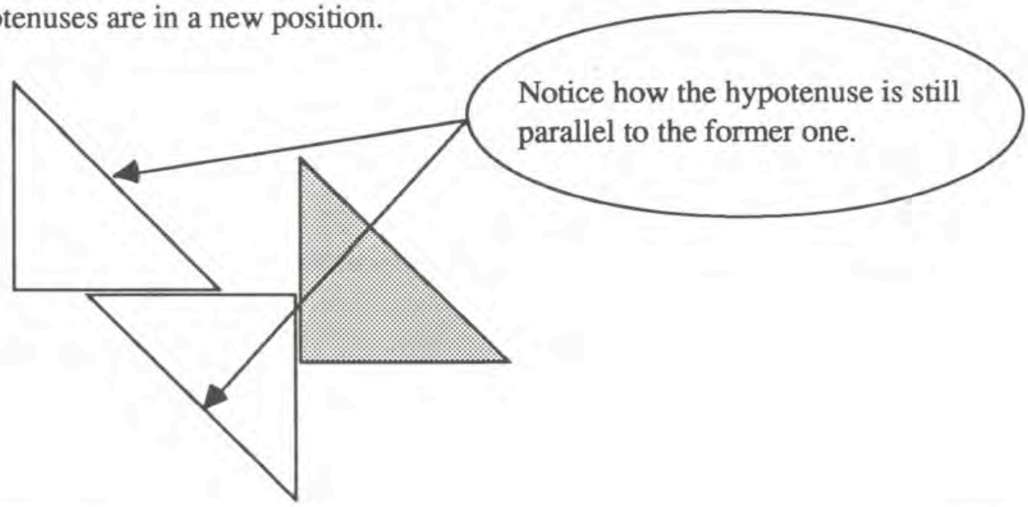
1. Fold the piece of paper in half and cut out two right angle triangles



2. Now arrange the right angle triangles so that the bases slide over each other

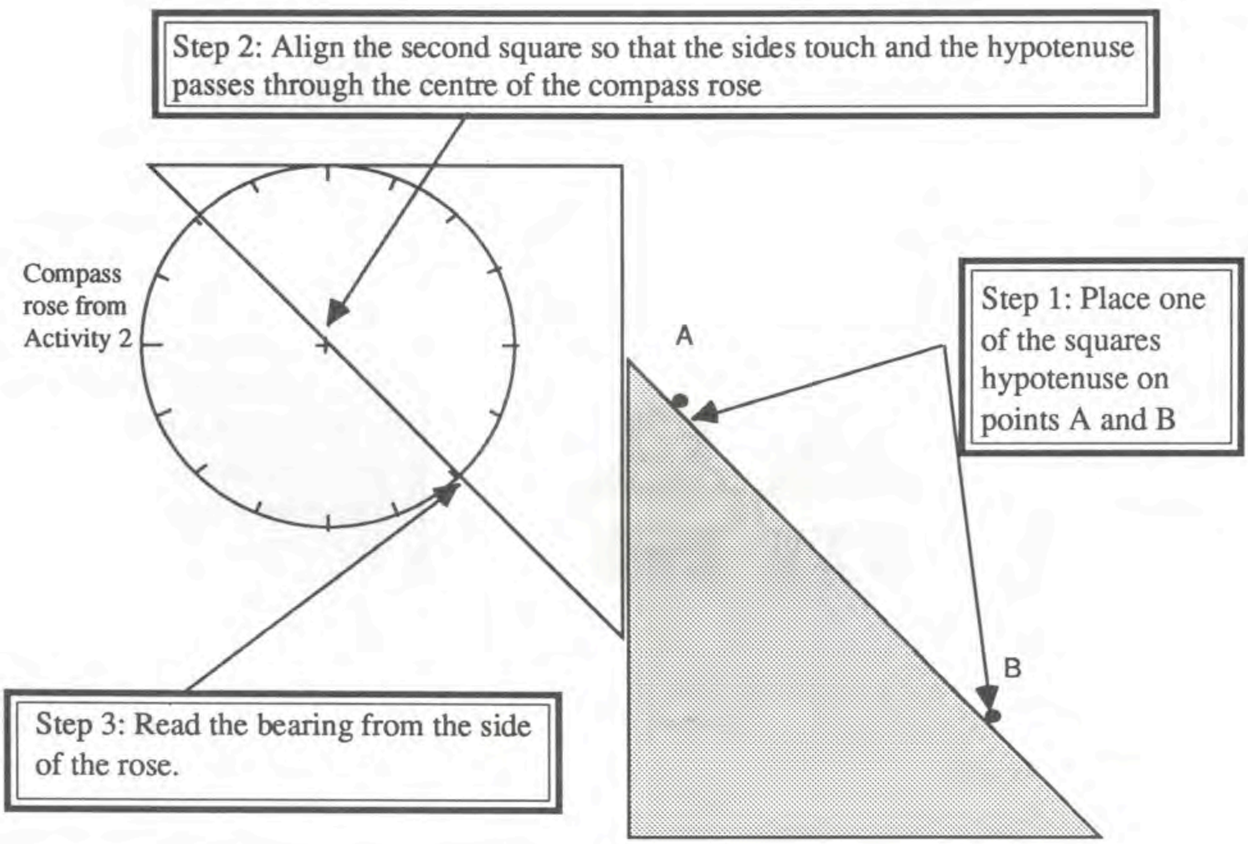


3. Now move one of the triangles to a new position so that the hypotenuses are in a new position.



4. Now cut out the compass rose you made in Worksheet 2 and paste it onto Worksheet 3 and use the parallel rules you have made to read the bearings from A to B, B to C and A to C.

5. If you read from A to B you read the bearing in the compass rose from the centre to the side. If you read from B to A, you would again read from the centre outward.



Before reading any bearing on a compass rose you need to be aware of the fact that magnetic north is changing each year.

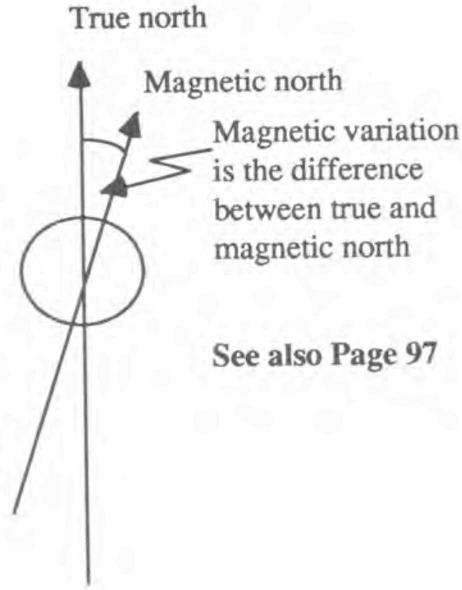
This is called magnetic variation and has to be taken into account before any reading is taken. In the southern hemisphere magnetic north is usually east of true north. True north is where the north pole is.

The variation changes annually and is printed in the centre of the compass rose.

Suppose the variation was 12°10'. The magnetic north pole would be 12°10' east of the true north pole. So your compass would be pointing 12°10' to the east of where true north was on the chart.

All bearings are given as true bearings on a chart. What the navigator has to do is tell the person driving the boat which way to point it.

Therefore the variation must be subtracted from the true bearing to give the course to steer.



See also Page 97

E.g.	True bearing:	0°
	Variation	12°
	Course to steer	348°

TRUE BEARINGS ARE GIVEN ON THE OUTSIDE OF A COMPASS ROSE. SOME CHARTS HAVE MAGNETIC BEARINGS

AS A GENERAL RULE IF THE ERROR IS EAST, THE COMPASS IS LEAST. i.e. you take off the variation when going from chart to compass.

ACTIVITY 2.3: READING BEARINGS ON YOUR LOCAL CHART

You will need

Your local chart
Your parallel rules
Worksheet 4 Page 87

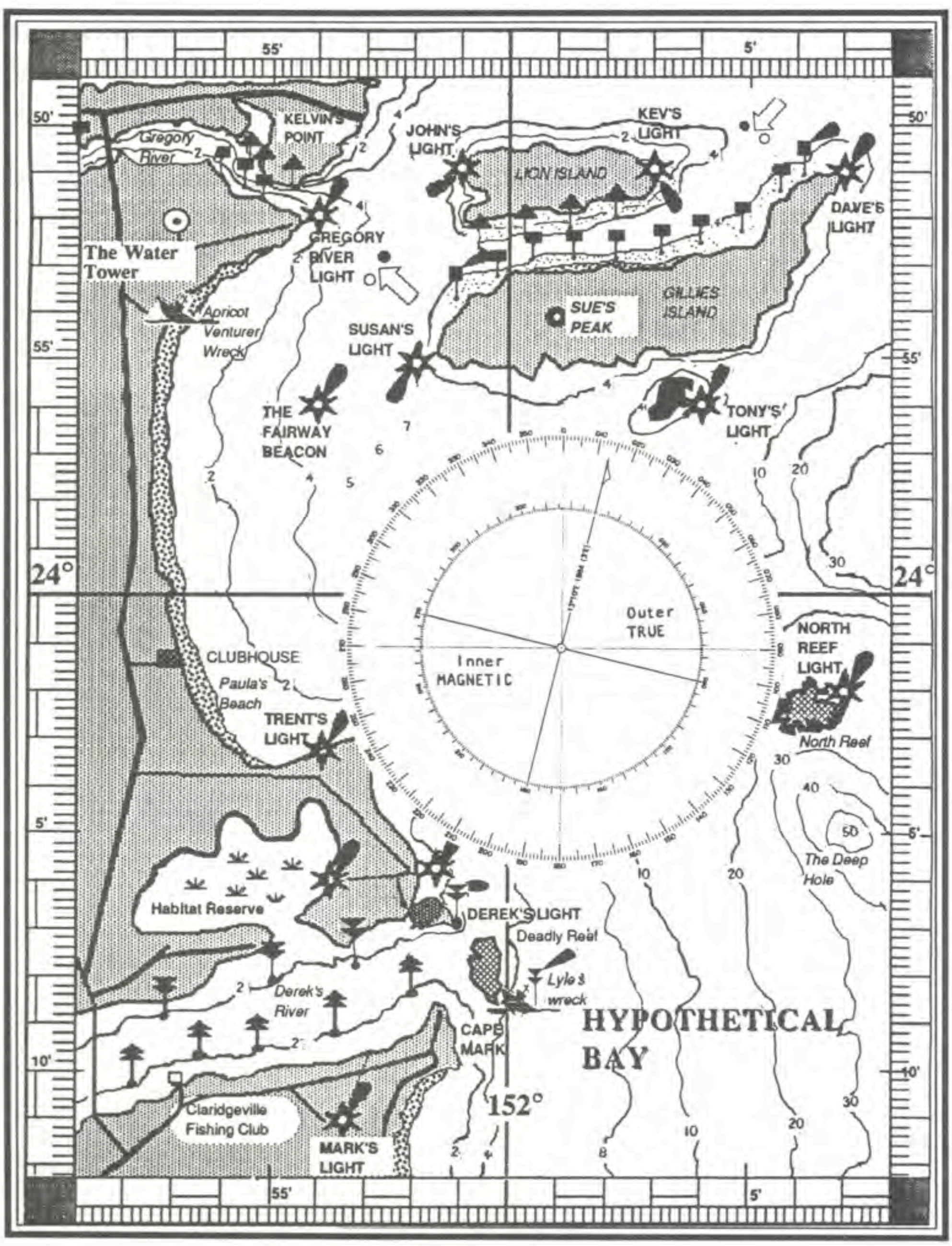
Have your teacher devise a course for you on your local chart with, say, six changes in course direction. Record these in the table on the worksheet as courses 1-6 noting where you are going from and to for each course.

Now use your parallel rules to read off the true bearings, and for each calculate the magnetic compass course you would steer. An example is given below:- (Error is 13°E)

Course from	to	True bearing	Magnetic bearing
1.Kings wharf	Fl .5s 10m 8M	260°T	247°C (260-13)

CHAPTER 3

HYPOTHETICAL BAY



PURPOSE

To introduce you to the language and skills of navigation

WHAT YOU SHOULD KNOW BEFOREHAND

Addition, subtraction, multiplication and division, how to use a ruler and how to use your parallel rules.

OBJECTIVES

You should be able to:-

* Identify the following features on a chart:- Capes, soundings, compass rose, reefs, lights, wrecks, channels, lines of latitude, longitude, buoys, beacons and marks.

* Recall the definitions for latitude, longitude, Greenwich meridian, distance, speed, time, bearings, nautical mile, pilotage, buoyage system, cardinal system, lateral system, safe water mark, port, starboard, magnetic and true bearings, course.

* Take readings from a chart in order to determine latitude, longitude, distance, buoyage system, a compass course, magnetic and true bearings to and from a compass rose.

* Make mathematical calculations in order to determine distance, speed, time, nautical miles, magnetic and true bearings.

* Use a chart in order to draw safe water marks and plot safe passages through inshore waters.

TIME REQUIRED

6 hours

HYPOTHETICAL BAY

(You will need a copy of the *Hypothetical Bay* chart from the back of this book page 92)

There are many things to learn about navigation. To navigate outside of the classroom requires skills and knowledge that come later in this set of notes. However for the present let us look at how to use A CHART. The one we will use will be Hypothetical Bay.

Hypothetical Bay is the *practice navigation chart* we will use to show you the basics of navigation. In the next chapter you will go navigating somewhere close to your school and will be required to take charge of a vessel's direction. This course is a **mastery one.** That is, everyone in it is expected to master the basics, and this is especially true of Hypothetical Bay. So how is the bay constructed?

Open your copy of Hypothetical Bay at the back of this book. Find the Deep Hole, which is due south of North Reef. From the Deep Hole, Cape Mark is clearly visible behind the cardinal south marker on Deadly Reef. To the starboard side you see Tony's Light which marks a small rocky outcrop behind Gillies Island with its prominent Sue's Peak.

You take a bearing on the water tower on the mainland near Gregory River, on the mainland before you turn into Derek's River Leading Lights to Claridgeville, pass the Habitat Reserve on your starboard side, and then into the Fishing Club for a cool glass of water before going home.

To the North of Claridgeville is Paula's Beach which has a point on which is Trent's Light. Further North is the wreck of the Apricot Venturer, which came aground in a storm of '82 and now lies rusty and broken.

The water tower near Gregory's River is a prominent landmark. Kelvin's Point is the northern-most aspect of the bay and to the east is Lion Island with John's Light to the west and Kev's Light to the east.

Now that the bay has been introduced to you, it is time to use it to learn the basics of navigation.

Fig 3.1: Hypothetical bay could be anywhere with a reef, cape and river inlets.

ACTIVITY 3.1: HYPOTHETICAL BAY

(Note: You can check your answers to the exercises on page 90)

You will need

Hypothetical Bay Chart
Pencil, Rubber and Ruler
Parallel Rules or set squares
Worksheet 5, Page 88

What to do

Read each section and answer questions as you go. Use the worksheets to organise your answers to the exercises and add more paper if you don't have enough space.

Exercise 1: Features of Hypothetical Bay Exercise

Look carefully at the chart and answer the following questions below:

1. Make a list of ten chart features that are not normally found on a map.

2. Can you name 10 possible user groups who you think might frequent the bay ? (e.g. *the local fishing club)*

LATITUDE AND LONGITUDE

The great advantage in the Mercator system of constructing charts is that everything is neat and "squared off". The world is divided into a grid of latitude and longitude. Lines of latitude and longitude appear as straight lines.

On a chart, the **Latitude** scale is marked in degrees and minutes on either side, while the **Longitude** scale is similarly marked on the top and bottom of the chart.

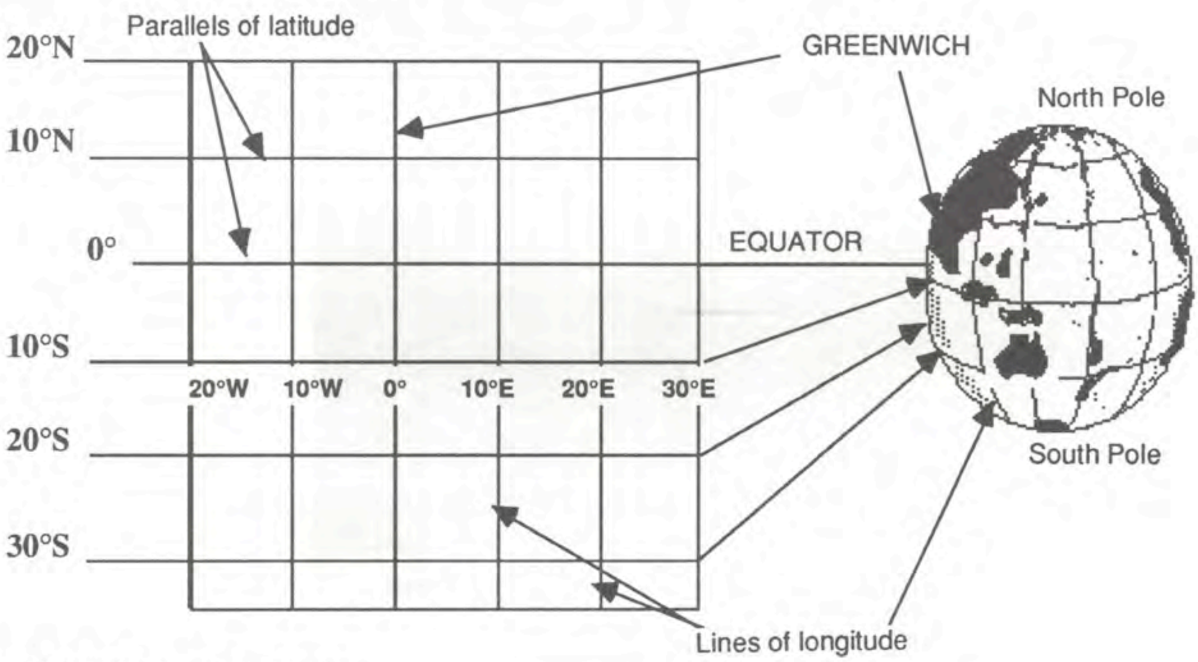


Fig 3.2 Latitude and Longitude

Because each is in the form of a circle, the scale of latitude and longitude is in degrees and minutes of an arc:

1 degree = 60 minutes (1° = 60') 1 minute = 60 seconds (1' = 60")	**The Greenwich Meridian** is the traditional starting place of all longitudinal measurements and is so named because it is the meridian of longitude that runs NORTH AND SOUTH through GREENWICH in London.

Fig 3.3: At Greenwich you can stand on either side of the world.

LINES OF LATITUDE ARE FOUND ON THE SIDES OF THE CHART

All degrees latitude on the chart for ***Hypothetical Bay*** range from 23°49' to 24°12'

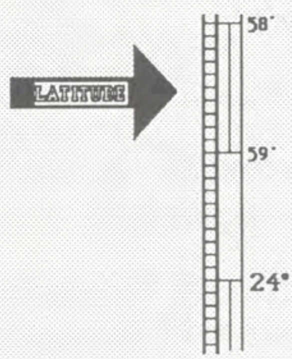


Fig 3.4: Lines of latitude are found at the sides of the chart

LINES OF LONGITUDE ARE FOUND AT THE TOP AND BOTTOM OF THE CHART

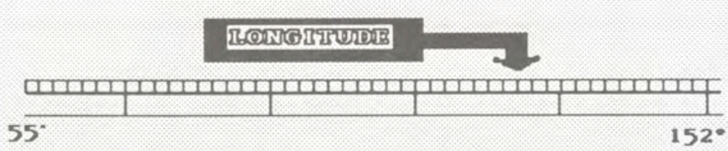


Fig 3.5: Longitude is at the bottom of the chart and runs east-west across the globe

Note: All degrees of longitude for ***Hypothetical Bay*** range from 151°51' to 152°08'

Every position on a chart can be pinpointed by a reading of latitude and longitude.

Any specific position is stated by first giving the line of latitude of its situation (in degrees, minutes and seconds) and then giving the line of longitude (in degrees, minutes and seconds).

Remember:

LATITUDE FIRST, LONGITUDE SECOND.

"A" BEFORE "O"

Exercise 2: Latitude and Longitude Exercise

Example:

Using the chart of Hypothetical Bay (1987) concentrate on *Fairway Beacon* .

Place your ruler from the centre of the LIGHT to the latitude scale on the right hand side of the chart (make sure your ruler is parallel to the scale at the top of the page.)

Read the latitude at that point on the scale.

DEGREES: Because it is under the 24° mark the latitude must be **23°** ....

MINUTES: Because it is four squares up from the 24° it must be 23° **56'**..........

DIRECTION: Because we are counting downwards from Zero, the equator, 23°56' **S**

So the latitude of the Fairway Beacon is **23°56' S.**

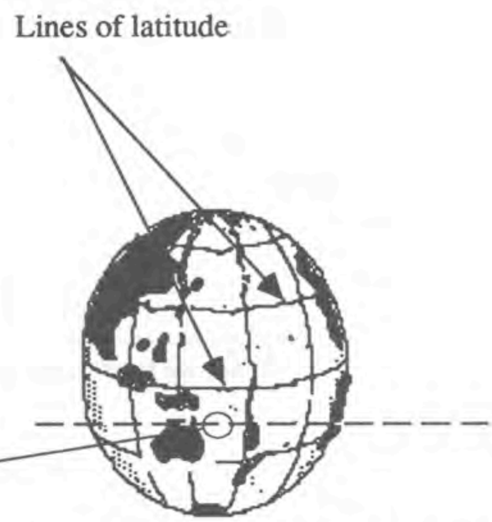


Fig 3.6: Latitude is always written first

What about the longitude ?

Place your ruler from the centre of the LIGHT to the longitude scale on the right hand side of the chart (make sure your ruler is parallel to the scale at the top of the page.)

Read the longitude at that point on the scale.

DEGREES: Because it is before the 152° mark, the longitude must be **151° ....**

MINUTES: Because it is four squares before the 152° mark, it must be 151° **56'...**

DIRECTION: Because we are counting in numbers that are increasing from Zero, or Greenwich, 151°56' **E**

So the longitude of the Fairway Beacon is **151°56'E.**

Fig 3.7: Longitude always follows latitude

This is written or spoken as ...position of Fairway Beacon... **23°56' S 151°56' E**

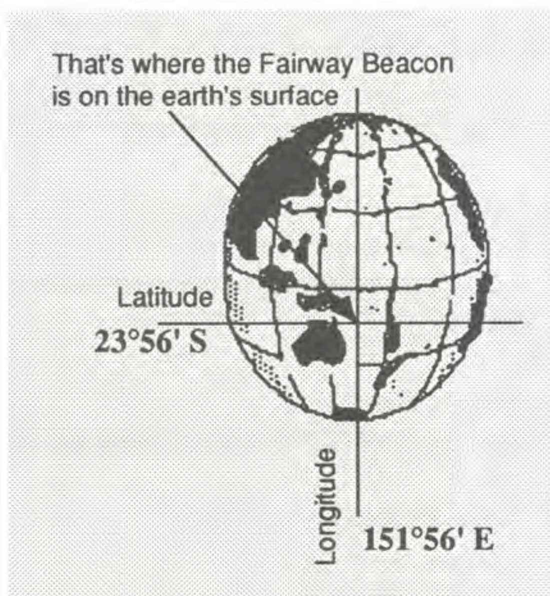


Fig 3.8: The latitude and longitude of the Fairway Beacon in Hypothetical Bay

Exercise 2: Questions

1. Find the latitude and longitude of the following points:

   (a) Gregory River Light
   (b) Susan's Light
   (c) Tony's Light
   (d) Lyle Wreck
   (e) Claridgeville Fishing Club

2. Name the charted features at the following positions of latitude and longitude

(a)	24° 10' S,	151° 53' E
(b)	24° 02' S,	152° 07' E
(c)	23° 51' S,	152° 07' E
(d)	24° 03' S,	151° 56' E
(e)	23° 54' S,	152° 01' E

3. Find two features at different latitudes but the same longitude.

4. Find two features at different longitudes but the same latitude.

You can check your answers on page 90

THE NAUTICAL MILE

Because the earth's surface is divided up in degrees and minutes, normal kilometres and metres are not used. The scale of measurement used is the *NAUTICAL MILE*, which is represented by *one minute of LATITUDE*.

1 Nautical Mile = 1 Minute of Latitude

Thus, few charts carry separate distance scales, the scale on the left or right side of the chart being used to measure nautical miles in any direction.

Fig 3.9 The Nautical Mile

Distance is measured by dividers. The spread of the divider's points are used to carry the measurement of the latitude scale, where it can be read off in minutes.

Because of variations due to the chart's distortion, distance readings should be taken from the LATITUDE scale at a point approximately level with the boat's position.

Exercise 3: The Nautical mile

Worked example:

What is the distance between the Fairway Beacon and Susan's Light ?

1. Take a ruler marked in cm and mm and lay it across the two lights.
2. Measure the distance to the nearest mm.
3. This is the distance in Nautical miles or Nm because the scale of the latitude on this practice chart is:

1cm = 1 Nm

Note: This is NOT TRUE of real charts, but we are simplifying the exercise using rulers

So the ***Answer is*** 2.3 Nm.

Exercise 3: Nautical mile questions:

What is the distance between the following points:

(a) Gregory River Light and the Fairway Beacon
(b) The Fairway Beacon and Trent's Light
(c) Gregory River Light and Susan's Light
(d) Tony's Light and North Reef Light

You can check your answers on page 90

DISTANCE

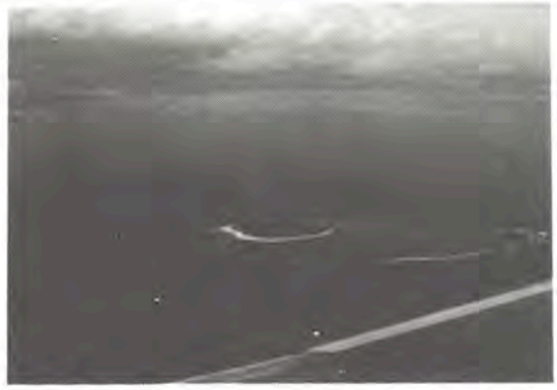


Fig 3.10: Danger circles are drawn around reefs and islands.

In the sea there are no roads, and the skill of the navigator is to determine the safest possible direction to take. This is done by drawing arcs of safe water.

When you calculate distance, you will have to draw these arcs with your mind's eye.

Exercise 4: Distance

Worked example:

What is the safest navigable distance between the Fairway Beacon and Tony's Light?

(a) Place your ruler on the two points and look at the depths of water around the line.

(b) Avoiding all water shallower than 4 m work out the shortest distance between the two points. Remember, you are NOT going to drive your boat up on to Tony's Island, but are going to round it.

(c) You have two choices;

(i) To the North of the Island.....the distance is about 7.8 Nm or
(ii) To the South of the Island.....the distance is about 7.5 Nm

(d) So the answer is:

Travelling to the South of Tony's Island, the safest navigable distance is **7.5 Nm.** However on the day, it may be blowing a gale and it may be better to take the longer distance to avoid the weather.

Exercise 4 Questions:

What is the safest navigable distance between the following chart features:

(a) Fairway beacon and Dave's Light
(b) Susan's Light and Kev's Light
(c) The Clubhouse and the southern tip of North Reef
(d) Claridgeville Fishing Club and the Deep Hole

You can check your answers on page 90

Now we will consider the time factor.

SPEED AND DISTANCE

These two factors are related by a formula that involves distance and time. Think of the speed of a car. It is measured in Kilometres per hour.

Speed is the total distance travelled, divided by the total time taken, and is written as

$$\textit{Speed} = \frac{\textit{Distance}}{\textit{Time}}$$

The speed of a vessel is measured by a speed log. This computes the time it takes to travel a nautical mile.

Speed is measured in knots. The term originated from the practice where a piece of wood, **the log**, was thrown overboard and allowed to flow out behind the boat. This line was marked in knots. One seaman would use an hour glass filled with sand to time the number of knots that flowed through the other seamans hand in a certain time. This indicated the speed of the ship.

$$\textit{Speed} = \frac{\textit{Number of Knots that flowed through Seaman's hand}}{\textit{Time it took sand to run through time glass}}$$

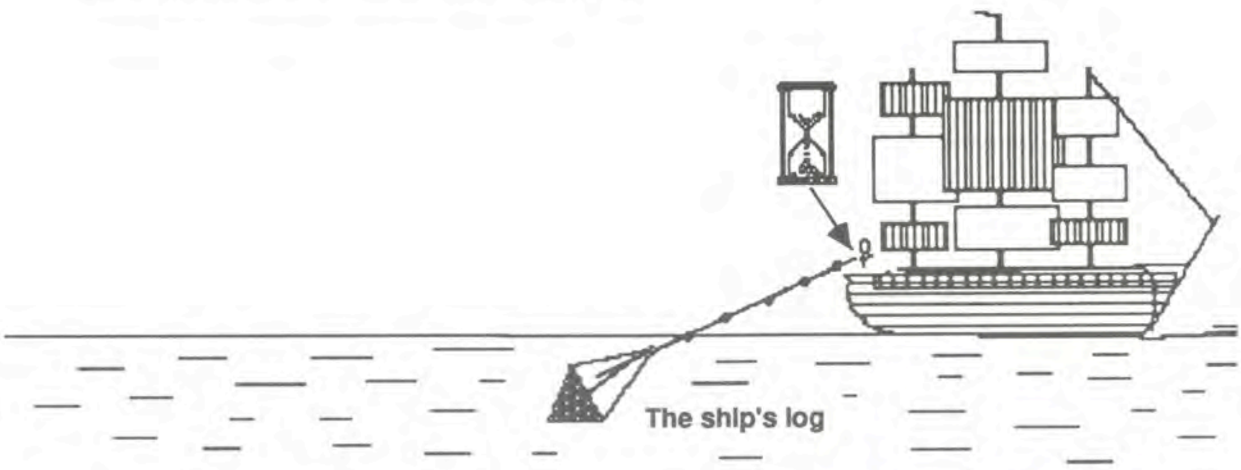


Fig 3.11: The sailor would stand at the stern of the vessel and count the number of knots at measured distances that passed through his hand in a certain time

Today , 1 knot is equal to 1 nautical mile per hour.

The log on a boat shows speed and distance.

Distance logs are more important because they can be combined with travelling time to compute a boat's speed.

A navigator may be called upon to calculate three possible factors:

$$\textbf{SPEED} = \frac{\textbf{DISTANCE}}{\textbf{TIME}} = \frac{\textbf{D}}{\textbf{T}}$$

$$\textbf{DISTANCE} = \textbf{SPEED} \times \textbf{TIME} = \textbf{S} \times \textbf{T}$$

$$\textbf{TIME} = \frac{\textbf{DISTANCE}}{\textbf{SPEED}} = \frac{\textbf{D}}{\textbf{S}}$$

The Magic Triangle

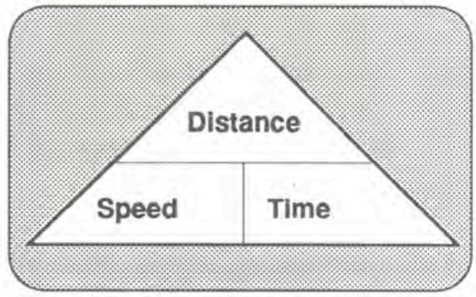


Fig 3.12: Relationship between distance, speed and time can be simplified by using this triangle. Cover one factor up and you get the formula for it.

It is easier to remember these formula with the distance, speed, time triangle. Cover one factor up and you get the formula for it.

Section 5: Speed and Distance.

Worked example:

(a) Find **the Speed**: How fast do I travel to cover 100 Nm in 5 hours ?

$\mathbf{S} = \frac{D}{T} =$ 100Nm/5hrs = 20 Nm/hr = **20 knots**

(b) Find the **Distance:** How far can I travel in 2 hours 30 minutes if I am travelling at 10 knots ?

T = 2hrs 30mins $= 2\,(\frac{30}{60})$hrs = **2.5 hrs**

D = S x T = 10 knots x 2.5hrs = **25Nm**

(c) Find the **Time**: How long is it going to take me to travel 75 Nm if my boat can travel at a constant speed of 10 knots ?

T = D/S = 75 Nm/10Nm per hr = 7.5 hrs = **7hrs 30 mins**

Exercise 5 Questions :

1. **Distance**

(a) How far can I travel in 10 hours if I am travelling at 9 knots ?
(b) How far can I travel in 6 hours at a constant speed of 4 knots
(c) For 2 hours I travel at 10 knots, and for the next 3 my boat can only make 5 knots. How far have I travelled ?

2. **Speed**

(a) My boat travels 10Nm in two hours. How fast did she go ?
(b) I left harbour at 7am and travelled 5 Nm till 10am. How well did my speed boat perform ?
(c) If I set out in my sailing boat at 10.30 am and reached my destination at 2.00pm after travelling 35 Nm, what was my average speed for the trip ?

3. **Time**

(a) How long did it take a mariner to travel 20Nm at an average speed of 5 knots ?
(b) Your sailing boat is travelling at 4 knots and your navigator predicts 32 Nm to go. How many hours will it take to reach your destination ?

Having calculated how far, how long, and how fast, you now wish to find out in which direction to steer the boat. This is where bearings become important.

You have already done some work on bearings in Chapter 2 with your parallel rules. Now we are going to do some more on Hypothetical Bay.

BEARINGS

You'll need Hypothetical Bay again and a set of Parallel Rules or a clear perspex ruler ! You can still use the set squares you made in Chapter 2.

This is where the real navigational skills come in. On a road map you can follow the roads. Calculating bearings is like making your own roads.

Bearings tell you where to head your boat. When you start your voyage, you will not be able to see where you are going. There are no signs, this way to Hawaii with road signs every 5 Nmiles. So you have to calculate the way. Here's how it's done.

Note: At this stage do not worry about magnetic variation, until you have a good grasp of the concepts. You will need a set of parallel rules. To use these you simply place them on the chart, and walk them over the chart so that each edge is kept parallel to the other.

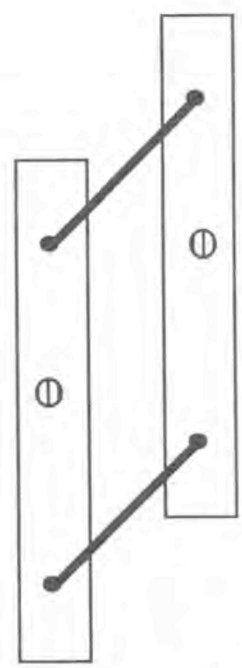
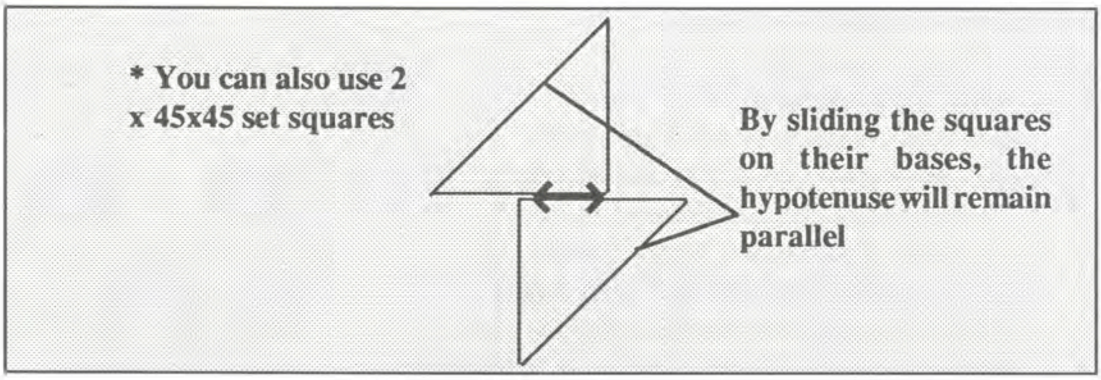


Fig 3.13: Parallel rules allow bearings to be taken to and from the compass rose.



Exercise 6: Bearings to help you go places

Worked Example:

Suppose you want to go from Derek's Light to the Tony's Light. It is thick fog and you want to know in what direction to steer your boat.

You will need a set of parallel rules or a clear plastic ruler.

Place the edge of the rule on the two chart features. Now carefully slide the ruler or walk the parallel rules, so that the rule passes through the small centre circle of compass rose and the degrees circle.

Read from the centre out in the direction you are going to travel. Read the inner or magnetic compass and *you find the bearing is 12° magnetic.*

Remember, read the bearing in the direction you are going to travel. If you were travelling from Tony's Light to Derek's Light then what would be the bearing ?

Did you get 191°?

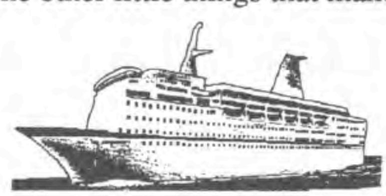
In real life situations it would be difficult to steer at 191° so we approximate our bearings to the nearest possible bearing.

In this case it would be **190°** from Tony's Light to Derek's Light, and **19°** from Derek's Light to Tony's Light. Is this a good idea for long ocean voyages over long distances? We will talk about that later.

So now that we have the direction, we start our motors or set our sails for 10° magnetic and travel at about 10 knots. How long should it take to get there? Did you get 11 hours?

This will be a rough guide. There are so many things that can slow you down:- a lost dinghy, a change of sails, a current that will push you off course and a hundred and one other little things that make the art of navigation difficult.

Let us assume ideal conditions and look at a few exercises.



Exercise 6: Questions on going places

1. What is the magnetic bearing from:
   (a) Tony's Light to North Reef Light
   (b) The Fairway Beacon to Sue's Peak
   (c) Tony's Light to the Trent's Light
   (d) John's Light to the Water Tower
   (e) Gregory River Light to Trent's Light
2. What is the magnetic variation for the chart ?
3. What does this variation increase by annually ?
4. What will be the variation in 1992 ?

PILOTAGE:- Going places close to shore

Pilotage is the term given to navigating local inshore waters using a set of buoys, beacons and markers that indicate where safe water is.

If you see cruise boats come into port you will often see a pilot boat accompany them. This boat has a person on board called a pilot, who has special local knowledge of the inshore waters so that the vessel can be safely guided into port.

Fig 3.14: A pilot boat is used to guide large vessels into port.

A whole range of markers have been used to mark where safe channels are. Each marker means something and indicates to navigators on which side it should be passed. The system of using markers in the sea is called a **buoyage system** and a particular port is said to be buoyed in a certain way.

Fig 3.15: In many small villages in the South Pacific, the system of buoyage relies on local knowledge.

THE CARDINAL SYSTEM OF BUOYAGE

In many different parts of the world many different markers are used in buoyage systems, however, a new international system called IALA has been adopted. It is called the cardinal system and is based on buoys which indicate where safe navigable water can be found.

The shape of the mark indicates that deep water lies in the indicated direction relative to the mark ie: North , south, east or west.

The cardinal mark indicated to the right with the two triangles pointed upwards indicates that deep water can be found to the north of the mark.

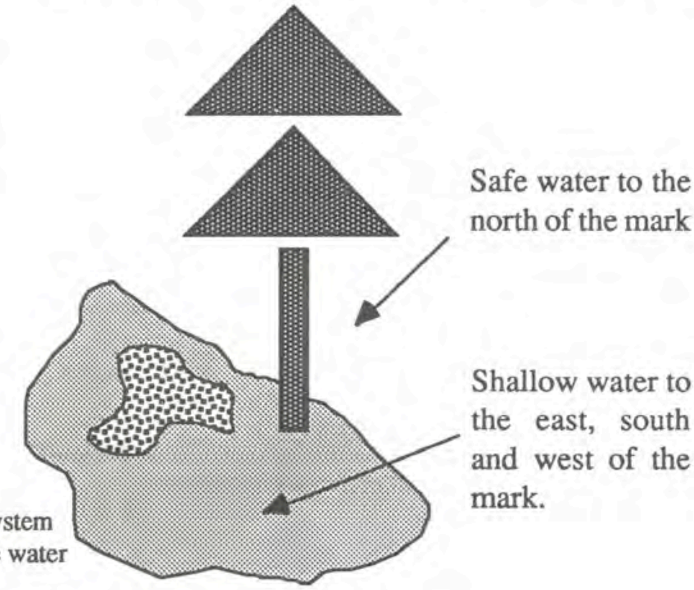


Fig 3.16: The Cardinal System indicates directions of safe water

The Buoyage System A can be summarised as follows

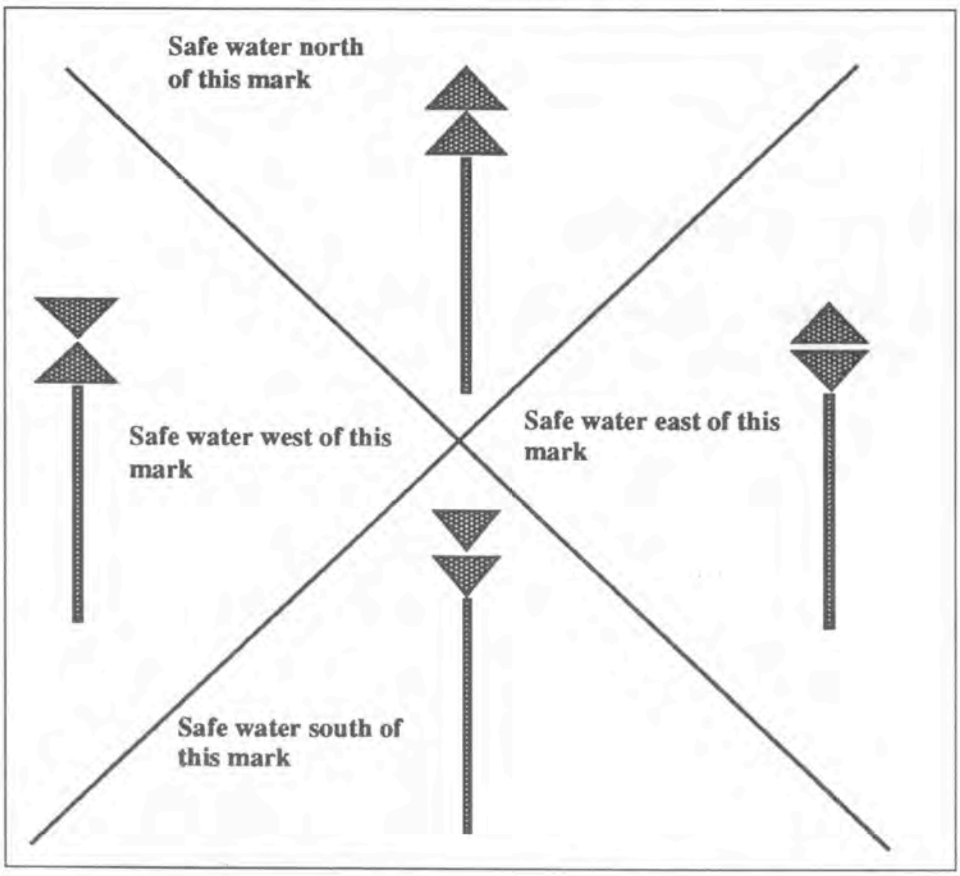


Fig 3.17: The Cardinal System of Buoyage is based on where safe water can be found

Exercise 7 Pilotage using the cardinal system

Worked Example:

Mark the safe water passage out from the habitat reserve off Derek's River.

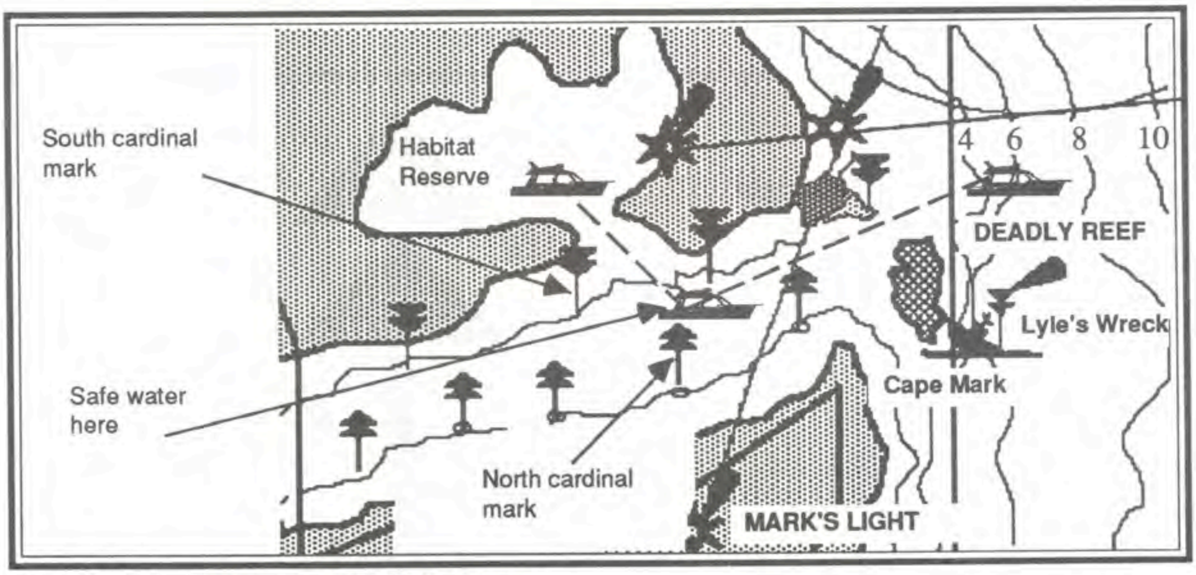


Fig 3.18: Safe passage out of the Habitat Reserve

Exercise 7 Questions on the cardinal system:

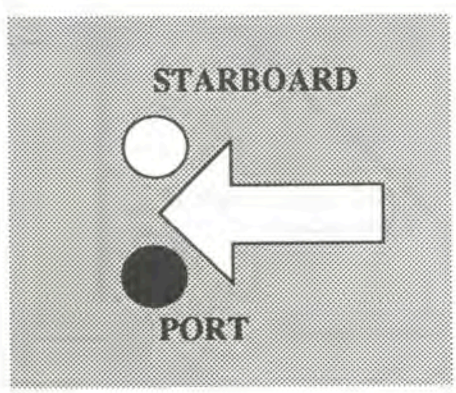
Q1. Name the cardinal marks in Derek's River
Q2. How deep is the water in which these marks stand?
Q3. You wish to pilot your way into Claridgeville Fishing Club from a latitude 24° 11'S, 152°01'E. Mark on the chart your proposed course avoiding all water below 2 metres

THE LATERAL SYSTEM OF BUOYAGE

This system uses squares and triangles to indicate the position of deep water. Red squares indicate a port marker and green triangles a starboard marker.

On a chart the direction is indicated by a symbol such as the one shown to the right. You can see this in Hypothetical Bay near Gregory River Light where the arrow points to the direction of buoyage.

Port stands for the left and starboard the right.



In System A when leaving port, the red markers are to the right and the green to the left..

In Buoyage System A when entering port the Red squares are kept to the portside (left) of the vessel.

HARBOURS MARINE
Caring for our coast

Fig 3.19: The lateral system of buoyage. Illustrations courtesy Qld Department of Harbours Marine

This is shown in Hypothetical Bay near Gregory River.

This is a starboard hand mark.

This is a port hand mark.

This is the direction of buoyage symbol indicating that you go this way to enter port and keep the port markers to the port side when entering the port.

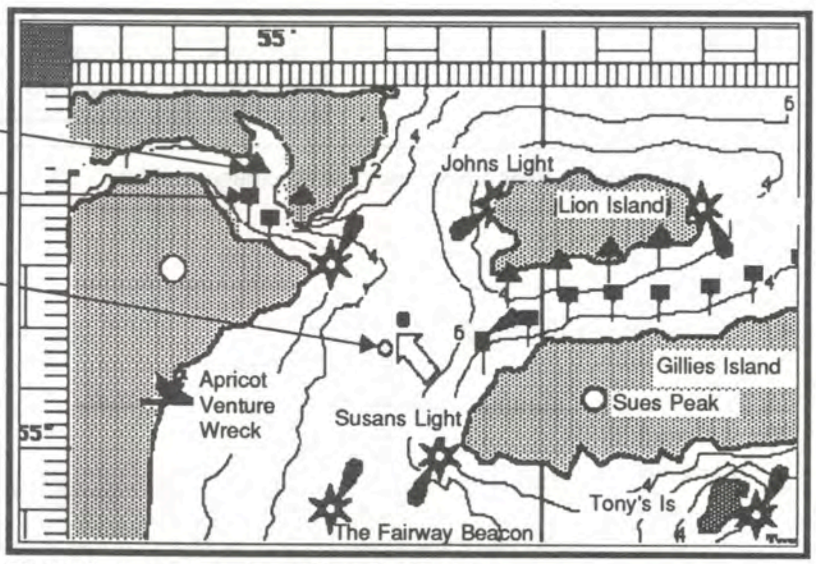


Fig 3.20: Lateral marks on Hypothetical Bay

Exercise 8 Questions:

Q1. How many starboard markers are there in Gregory River?

Q2. Mark a safe course down the channel between Gillies and Lion Islands.

Q3. You are leaving port and see this marker. Which side do you pass and why?

Fig 3.21: A port hand mark

DETERMINATION OF POSITION AT SEA

Now that you have left port, the first thing you want to know is where you are. This is called determination of position at sea, and involves taking bearings on known positions and using the compass rose.

Firstly, remember how you took bearings to the nearest 5°. Now imagine you are out in Hypothetical Bay and wish to return home from outside Wreck Reef.

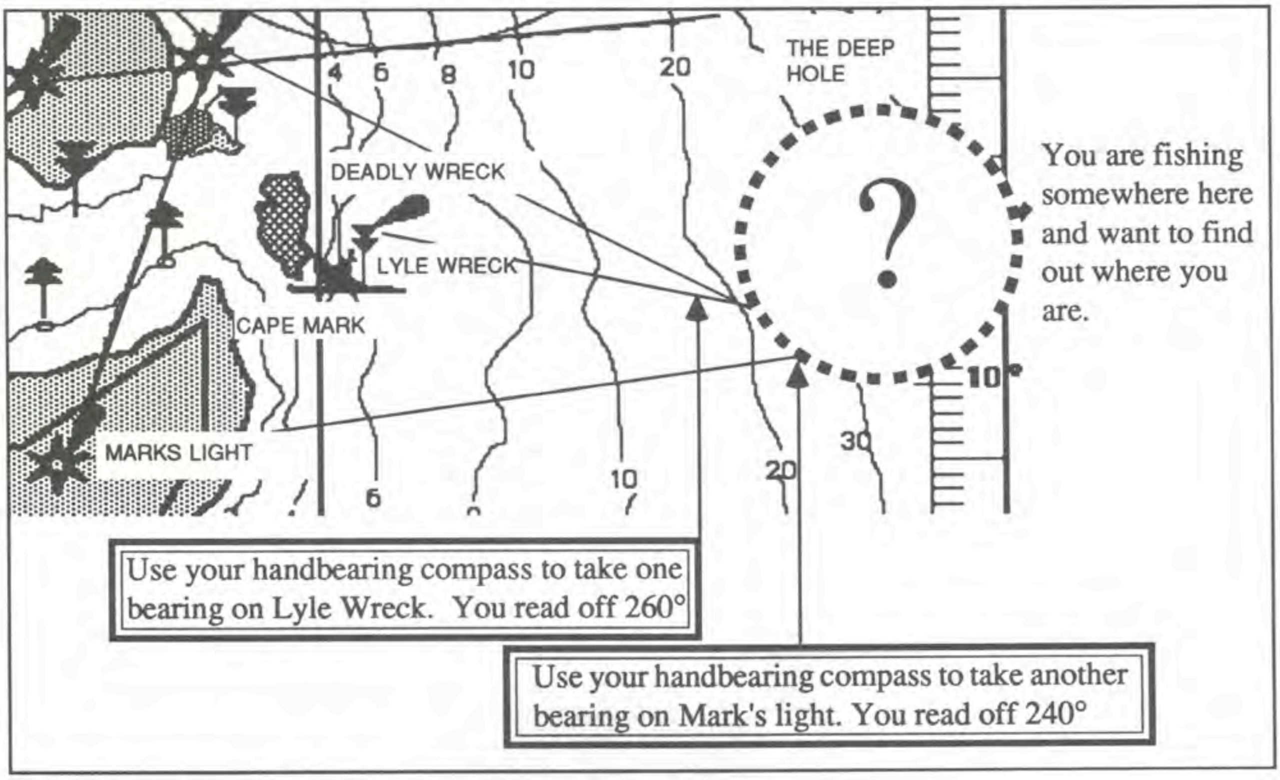


Fig 3.22: Three bearing fixes are necessary to determine position

Record these as:	Bearing A to Lyle Wreck	260°Compass	270°True
A Three Bearing Fix will result in a Cocked Hat	Bearing B to Mark's Light	240° Compass	250° True
	Bearing C to Derek's Light	285° Compass	295° True

Remember, always convert to true bearings, as some charts do not have a magnetic compass rose.

Now that you have your true bearings, use your parallel rules to walk from the compass rose to Lyle Wreck and draw a line out to sea on the hypotenuse.

Now do the same for Mark's Light.

Where the two lines intersect is your approximate position.

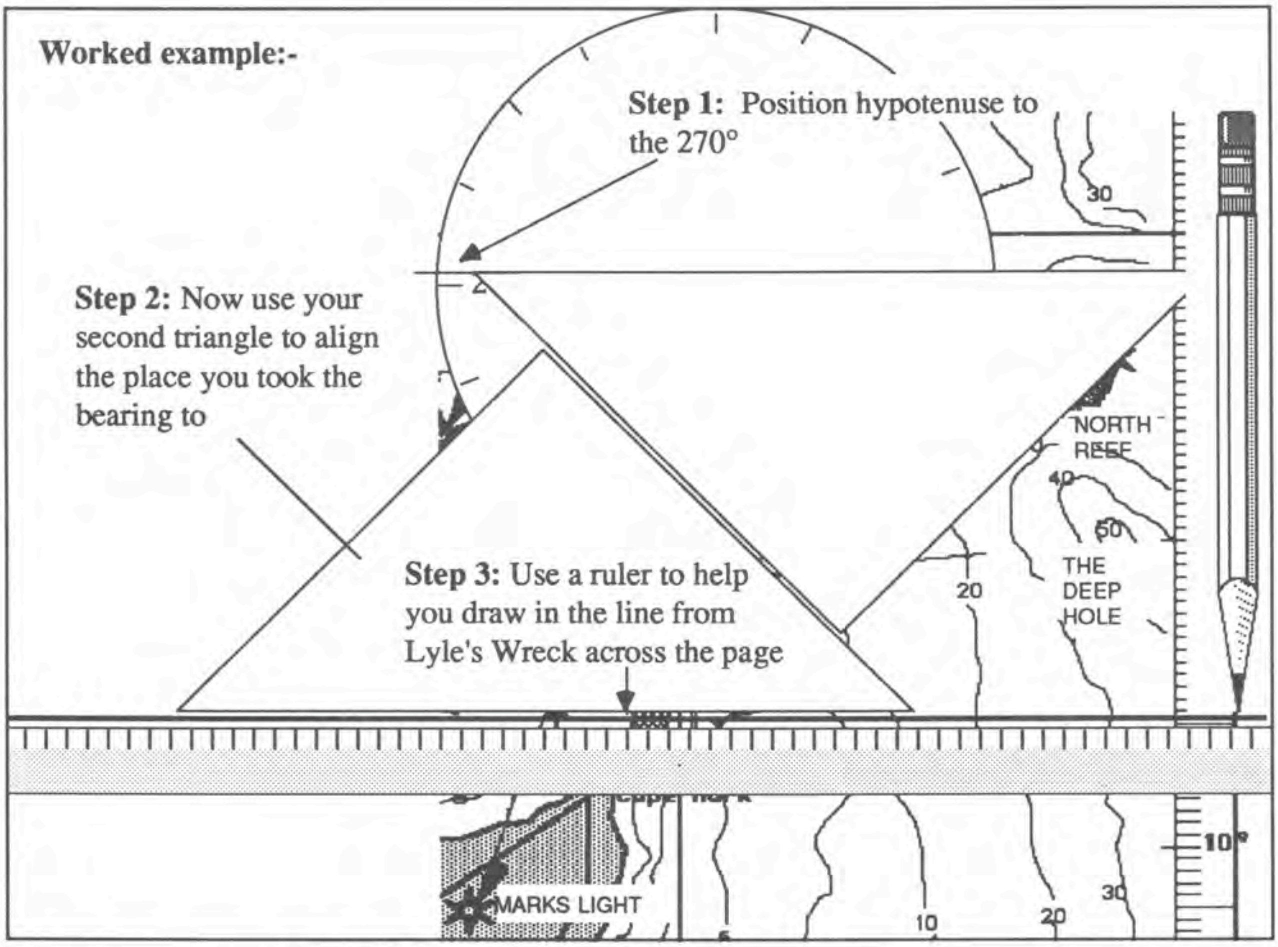


Fig 3.23: Use your triangles and ruler to draw in the bearings

Now repeat the operation for the bearing you have on Mark's Light and the leading light at the mouth of Derek's River. You now have three lines which intersect just south of the Deep Hole.

The smaller the triangle the more accurate the bearings and the more accurate the position fix. The resulting triangle is called a cocked hat because it resembles a witch's hat.

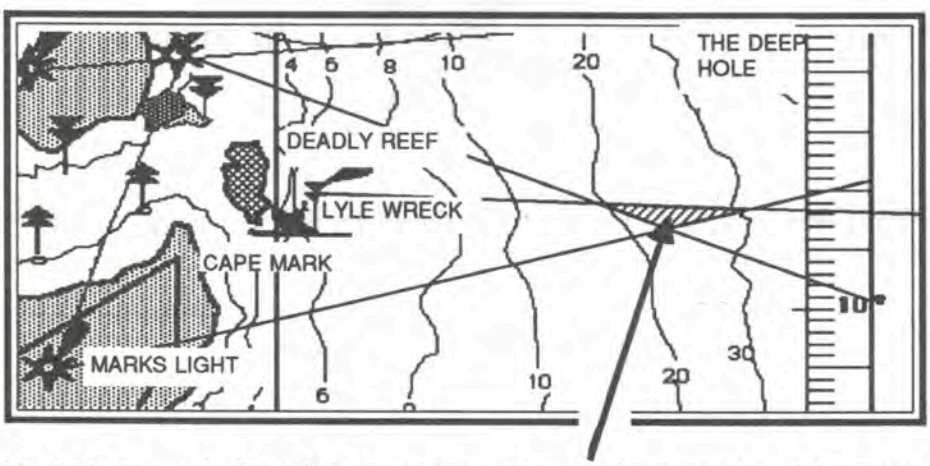


Fig 3.24: The cocked hat gives the navigator the approximate position of the vessel. The position is only as good as the bearings the navigator receives.

Exercise 9: What's your position?

For each of the following bearings determine the approximate latitude and longitude for a vessel moored in Hypothetical Bay. In each case convert the compass bearings to true, and record these in the table on Worksheet 5.

Position 1:
Bearings are: *To Trent's Light 235°C, to Tony's Light 305°C, To North Reef Light 160°C*

Position 2:
Bearings are: *To North Reef Light 95°C, To Trent's Light 155°C, To Sue's Peak, 45°*

Position 3:
Bearings are: *To Gregory River Light 255°C, To Sue's Peak, 120°C, To Trent's Light 180°C*

NAVIGATION LIGHTS AND SIGNALS
(see also page 96)

Boats without navigation lights at night are a danger to all. It is important that a vessel be properly fitted out with lights for night time.

The rules for preventing collisions at sea state clearly what lights need to be carried. The lights below show one interpretation of the rules.

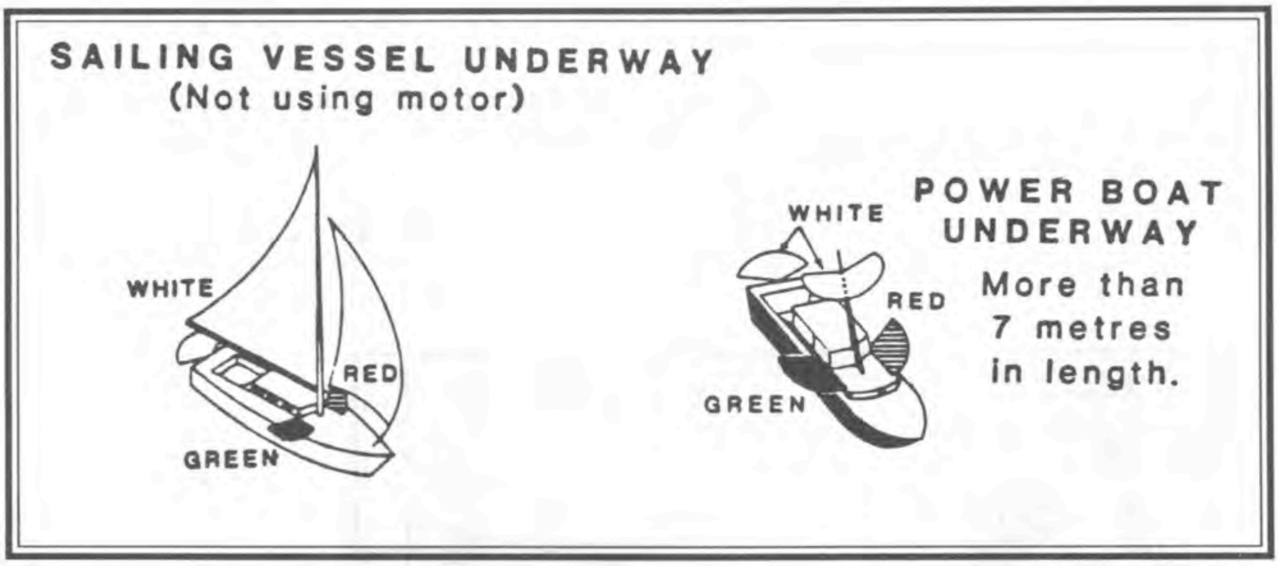


Fig 3.25: Some navigation lights. Illustrations courtesy Department Harbours Marine.

THE INTERNATIONAL DIVER'S FLAG

This flag is used to show that a diver is down underwater and caution should be exercised when approaching boats or vessels displaying this sign.

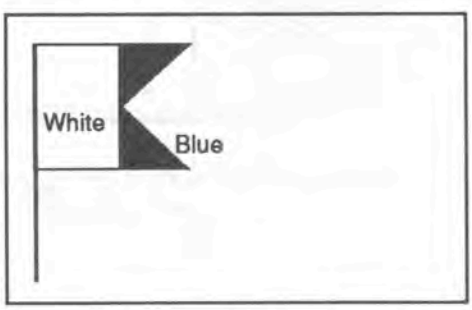


Fig 3.26: The international diver's flag

SPECIAL MARKS

Channel markers are used to indicate the intersection of two channels. The crosses usually indicate the direction where the channels meet.

Fig 3.27: A channel marker

LAYING OFF YOUR OWN COURSE:

On a new chart of Hypothetical Bay, plot out the legs of the course described by the fisherman below.

Construct a course table similar to the one you have just completed for the scientist, leaving off the ETA and ETD.

Worked Example:

A day's fishing is planned. We have a 16 ft (3.9 m) runabout with a 70 hp motor and plan to travel at 15 knots at a variable speed to and from the Fishing Club Jetty at Claridgeville.

We want to lay off a course from the Claridgeville Fishing Club, down Derek's River to Derek's Light and then to the Deep Hole. Circle North Reef and return to the Clubhouse. Here are the steps we will follow:

Q1. Work out the distance, times and bearings for each of the "legs" in the trip and enter them into the table below:

From	to	Bearing	Distance	Speed	Time	Notes
Fishing Club Jetty	Main Stream	10°	1 Nm	5 Knots	12 mins	
Main Stream	Derek's Light	55°	6 Nm	12 Knots	30 mins	
Derek River Light	The Deep Hole	65°	8 Nm	16 Knots	30 mins	Fish for 1 hour
The Deep Hole	North Reef Light	350°	3 Nm	6 Knots	30 mins	Troll for mackerel
North Reef Light	Safe Water North	295°	1 Nm	12 Knots	6 mins	
Safe Water	Derek's Light	220°	9.5 Nm	9.5 Knots	60 mins	
Derek's light	Mainstream	235°	6 Nm	12 Knots	30 mins	
Mainstream	Fishing Club Jetty	210°	1 Nm	5 Knots	12 mins	
Totals		-	34.5Nm	-	210 mins	60 mins

Q2. How long can you spend fishing at the Deep Hole if you leave home at 9 am and return home at 3 pm?

Q3. This chart now becomes important for calculation of petrol. Suppose your fuel tank holds 40 Litres. Your petrol use is 1 Nautical mile per litre. How much petrol will you need for the day?

Answers:

Q2. Total 6 hrs = 360 mins Travel 210min Time left = 150 mins .

Q3. 34.5Litres . Use 37Litres

SOME NAVIGATION RULES

To prevent collisions at sea the following navigation rules have been adopted. There are others but for small craft using inshore waters, an ability to apply these rules will save much embarrassment and avoid collisions.

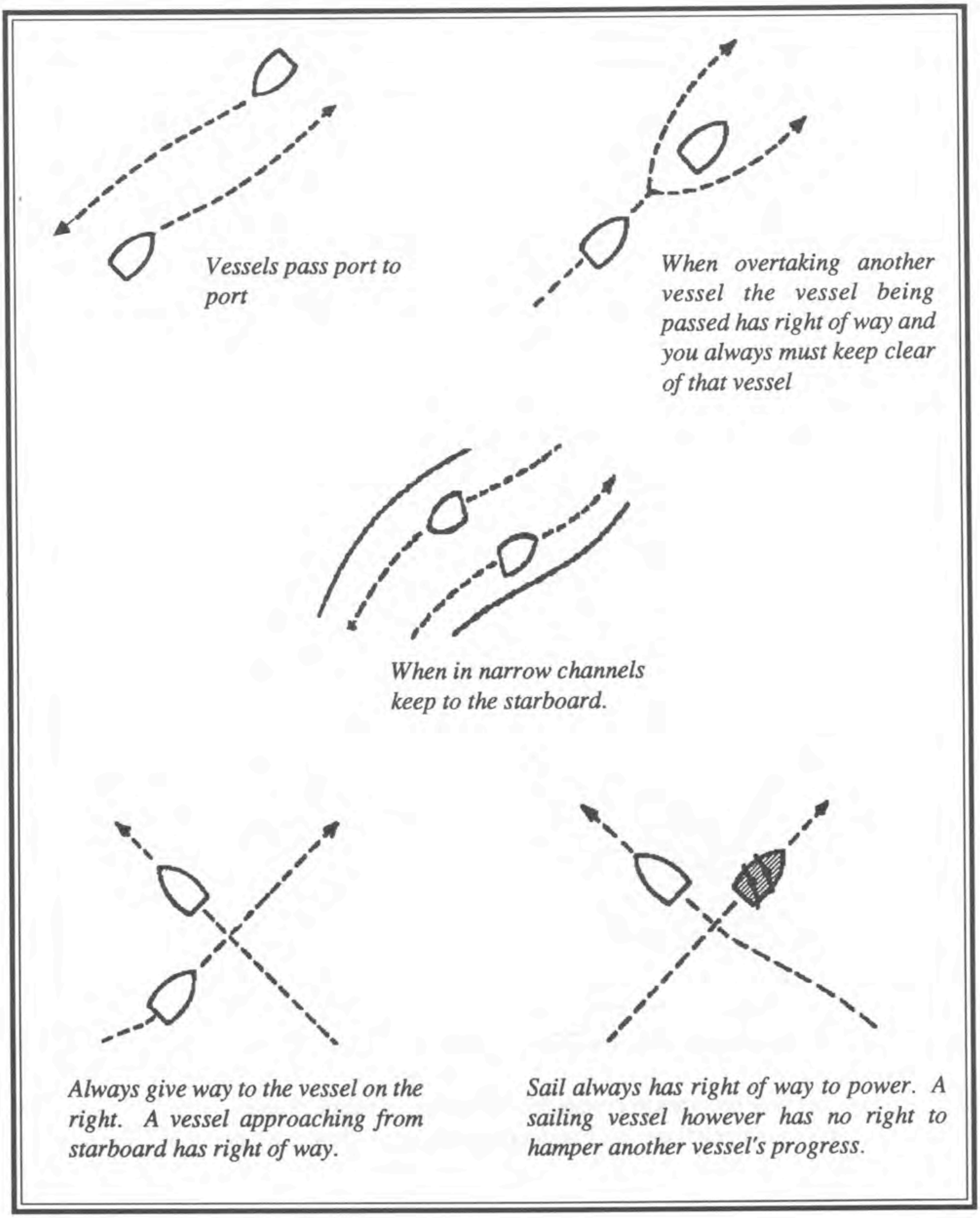
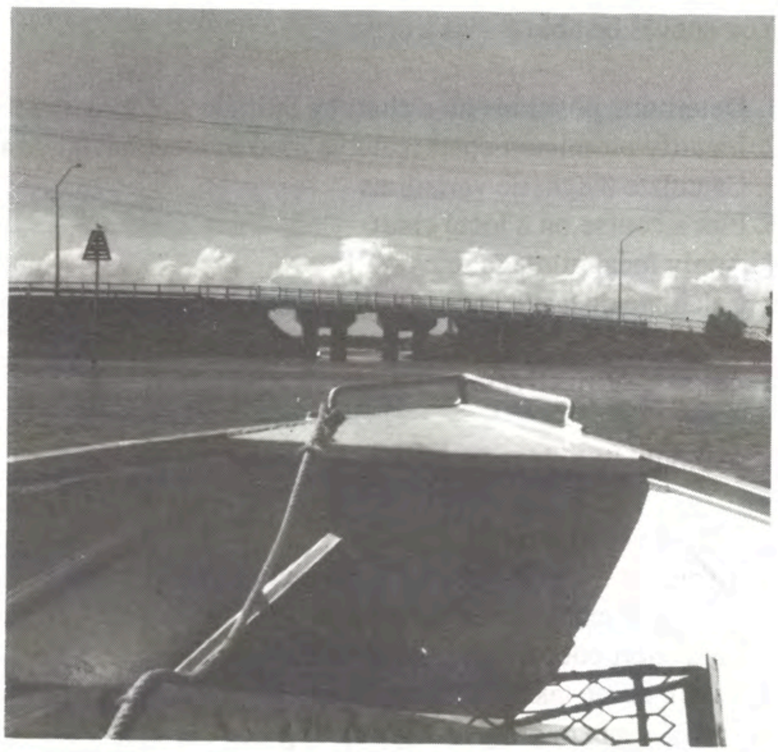


Fig: 3.28: Some navigation rules

CHAPTER 4

FIELD WORK



Purpose:

To enable students to:-
1. Apply the skills learned in Hypothetical Bay to a real chart.
2. Go to sea with that chart in order to practise the above skills learned in the classroom.

Pre-requisite skills:

You should be able to:

1. Read a compass and take a bearing of a distant point.
2. Recognise significant features on a chart.
3. Use a set of parallel rules or set square to work from, and a compass rose.
4. Correct for magnetic declination.
5. Work simple distance/time/speed calculations.
6. Take readings from a chart in order to determine latitude, longitude, distance, buoyage system, a compass course, magnetic and true bearings to and from a compass rose.
7. Make mathematical calculations in order to determine distance, speed, time, nautical miles, magnetic and true bearings.
8. Use a chart in order to draw safe water marks and plot safe passages through inshore waters.

Time Required:

2 hours classroom work
One day (depending on class size and distance from the sea).

Classroom Objectives:

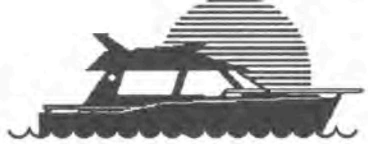
You should be able to, as a class:-

1. Determine positions on a chart by latitude and longitude
2. Identify prominent chart features used in local navigation
3. Calculate magnetic variations
4. Plot a course on a local chart
5. Apply local pilotage rules
6. Calculate distance speed and time problems

Excursion Objectives:

You should be able to as a class:-

1. Pilot a vessel out of a harbour
2. Anchor at a predetermined point and find your position using the "cocked hat" method
3. Set a short course and predict time of arrival
4. Return home taking running fixes and predicting times
5. Work co-operatively as a group to guide the vessel safely at sea



A local ferry boat chartered for the day proves ideal, because it gives the whole class a chance to get aboard. Also there is plenty of room for charts and plotting at sea. Check to see if the launch hired has a current certificate of survey and that the launch master has the required launch master's certificates.

Life at sea is different from life on land. It takes more effort and more time to work. A lot of time is spent in preparation and cleaning up. People can be affected in many different ways by sea experience and you will have to learn to help and/or tolerate these individual differences.

ACTIVITY 4.1: A DAY'S NAVIGATION

Part A: Materials Required before you go

* *A copy of the worksheet on page 90*
* *Parallel rules (or set squares)*
* *Local Chart with compass rose*
* *Dividers*
* *Hand bearing compass*
* *Binoculars (optional)*

Part B: As you leave the harbour you will study the Buoys, Beacons and Marks

As the vessel leaves the harbour/jetty, there will be a set of lateral marks that will guide you out of the harbour. Make a drawing of each one you pass, and note which side (port or starboard) the vessel passes. The cardinal system of marks is being introduced in Australia and you may or may not see them.

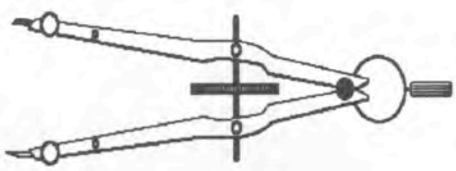
Part C: Now that you are out of the harbour, anchor in a safe place and find your position.

One of the first things to do is to find out where you are. Ask the skipper to anchor the vessel a short distance out. Then take 3 bearings on points that you can locate on your chart. Using your parallel rules or squares, work from your bearing on the compass rose to the point on land/sea from where you took the bearing. You will need to think back to the time you navigated your classroom and how you found your position there.

If there is more than one mark and these are close together, then use binoculars to check accurately that you have taken the right one.

Now record your latitude and longitude (or Grid reference).

Position Fixing



From where you are anchored take 3 bearings to points that you can locate on the chart and write them in the table on the worksheet.

Now using squares and the compass rose DRAW lines to locate your position.

Part D. Now that you have found where you are, plan to go somewhere by Plotting a Course.

In this part of the exercise you will work out three legs of a course, their distances and the times each will take to complete.

For the first leg

Decide on a short leg, say 1 nautical mile. Work out a safe course avoiding all shallow water, and try to end up at a marker buoy or island. Fill out a copy of the table of the worksheet on page 90.

LAY OFF A COURSE involving 3 or 4 changes of course and fill in the table below. Then set off ón that course.

Day's log:____________ Date:__________

Time Position	Distance travelled	Fixes from	Fixes to	Boat Speed

Make the necessary magnetic corrections to get to the compass course then ask the skipper to proceed at a set speed. Estimate the time you should take as an extra check. Now take 3 bearings and check your position and mark your chart.

For the second leg

Decide on a longer course at a different speed with three aims in mind:

(a) to learn to take running fixes
(b) to locate position at any given time
(c) to estimate the bearing at the end of the course

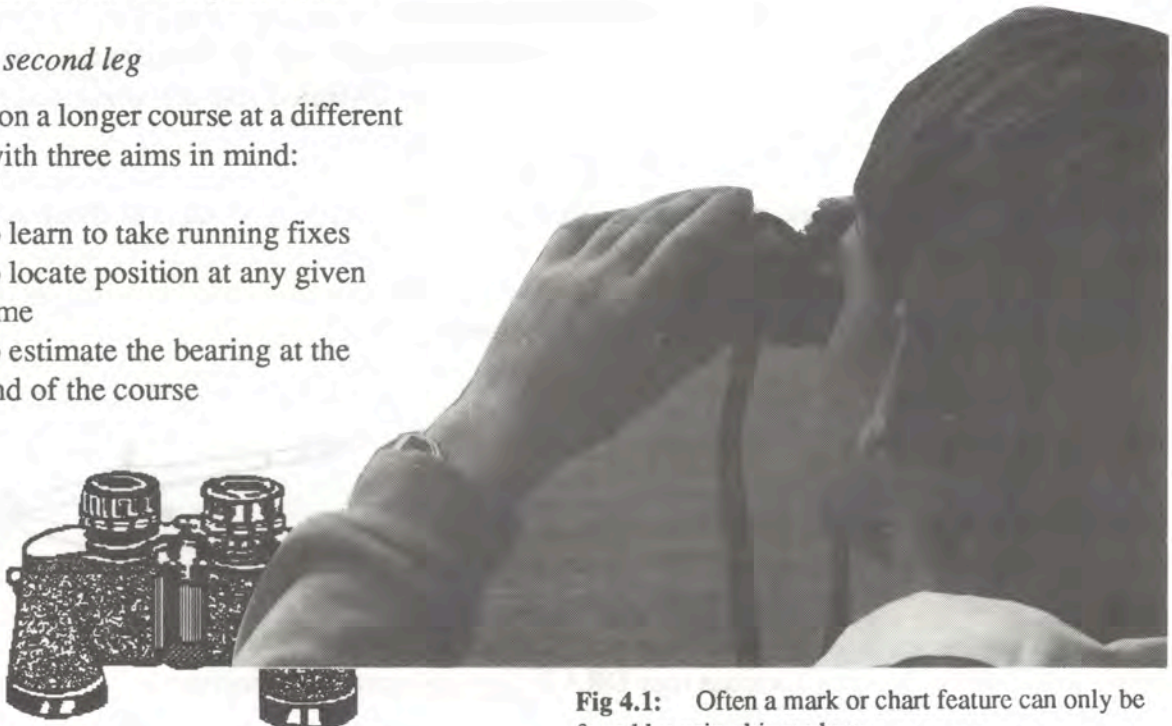


Fig 4.1: Often a mark or chart feature can only be found by using binoculars

Part E: Now that you think you are pretty good, see if you can get back and take running fixes.

For the last leg

Here is a chance for you to see how good you are. When you are about to start the last leg of your course, find somewhere in the vessel where you cannot see where you are going. Imagine that it's pitch black and you have to navigate with only a compass. To do this you will have to work well as a group and co-operate with the skipper.

Lay off your course, work out the speed/distance/time sums and set off. With your chart, compass and dividers ask for running fixes so as to plot your position. Ask for checks to be done along the way on landmarks. When you come to the end of your calculated time ask the skipper to stop and check your position. This is what the job of a navigator is like with skipper and crew working together.

As you come into port record the buoys, beacons and marks and on which side (port or starboard) that the vessel passes.

Part F: Your report

Write up your report as your teacher directs you. You should show that you are able to:

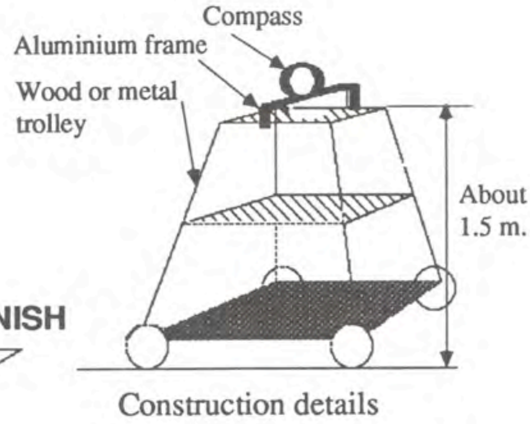
(a) Plot a position fix (Part A)
(b) Plot a course and calculate speed/distance/time sums
(c) Lay off a course in order to estimate time of arrivals
(d) Compute latitude and longitude and do a running fix in order to locate position at sea for any given point in time.
(e) Complete the worksheet for the excursion.

Fig 4.2: Once a chart feature has been found a compass bearing is taken on it. Here a student from the Darling Point Special School sites a bearing. The student can see the numbers inside the handbearing compass

ACTIVITY 4.2 NAVIGATING YOUR SCHOOL (or school oval)

Boat construction

First you have to make your boat. Study the diagram and photographs below and see if you can make one for your class.



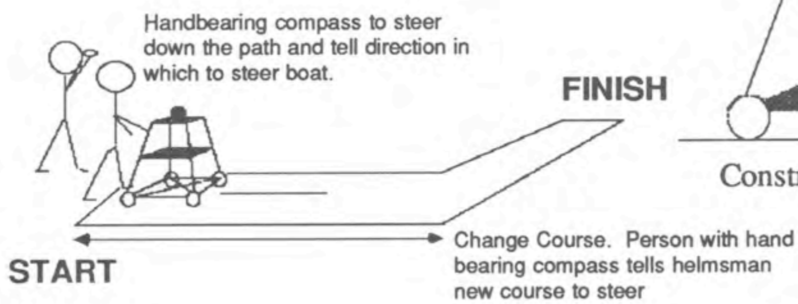


Fig 4.3: A boat trolley can be made from an old desk, some wheels and a small boat compass mounted on timber in top. A tray underneath can be used to hold charts of the school, parallel rules and handbearing compasses.

Make a map of your school

You will need to prepare a map of your school so that you can ask others to navigate around it. This is a time consuming task and will need to be developed over a number of years.

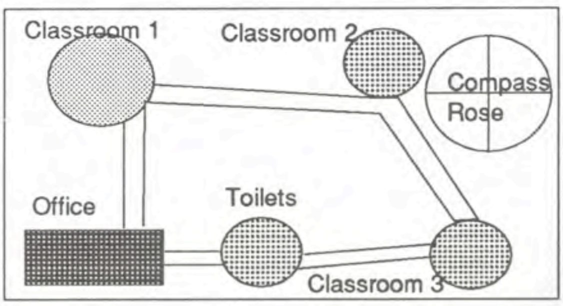


Fig 4.4: Plan of the school to be navigated.

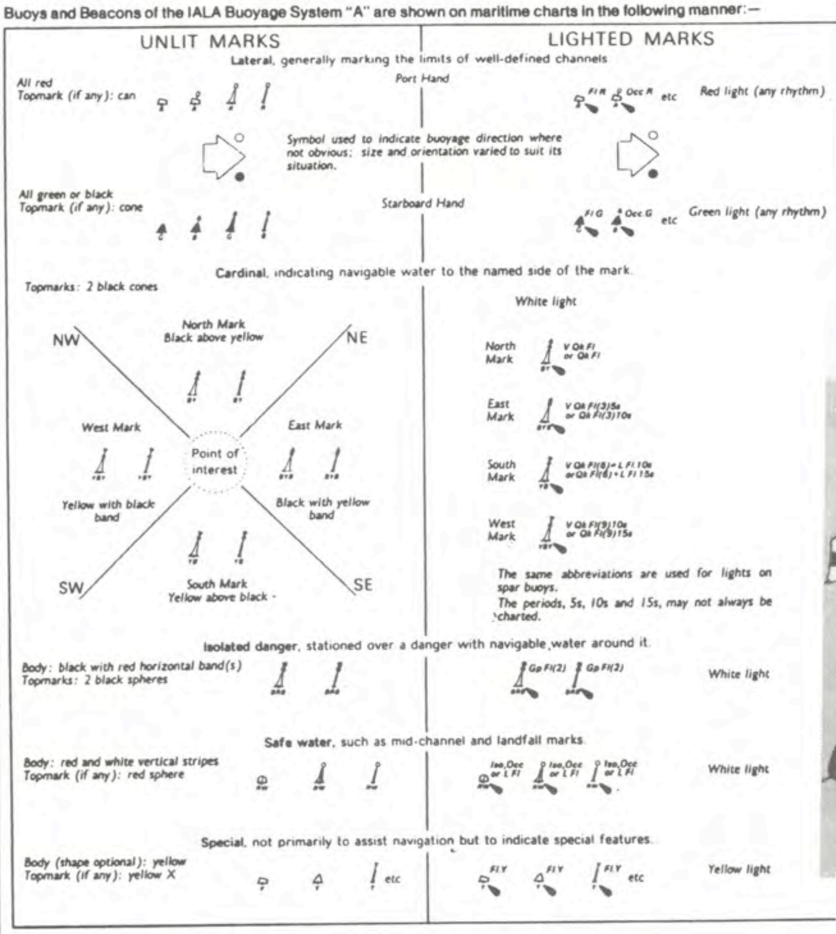
Once prepared the map can be used by classes that follow you.

Fig 4.5: Model trolley used in exercise

BUOYS, BEACONS & MARKS

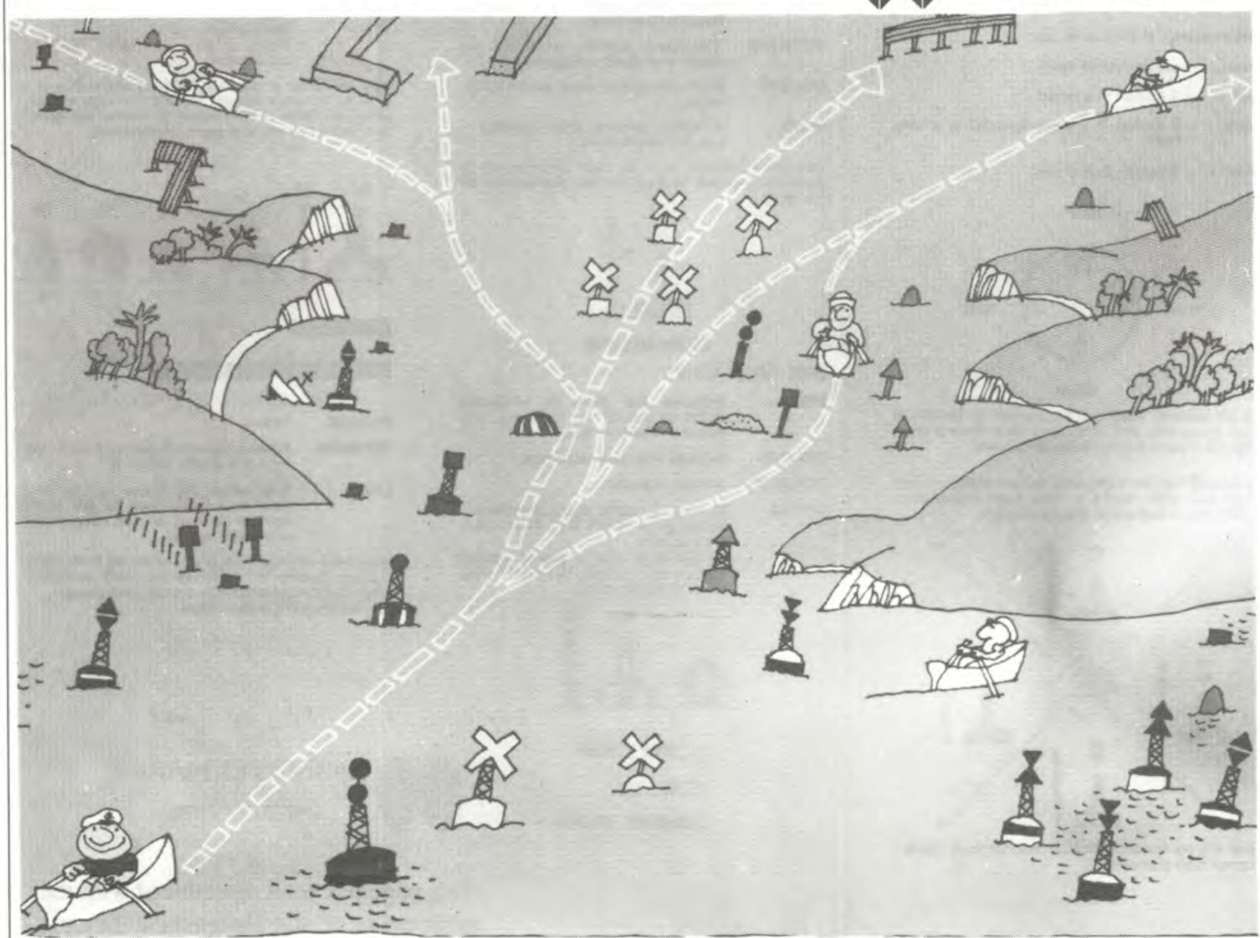
THE IALA MARITIME BUOYAGE SYSTEM "A"

Buoys and Beacons of the IALA Buoyage System "A" are shown on maritime charts in the following manner:—



HARBOURS MARINE

Caring for our coast



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The Buoyage System

Road signs on the State's highways are designated to enlighten the motorist of **possible dangerous situations**, similarly the Maritime version of these signs — buoys and beacons **carry out a parallel function on the water-ways**.

On sighting a navigational mark, every Mariner's reaction should be **instinctive, positive and correct**. He must decide immediately which way to go.

Lack of knowledge of the buoyage system could result not only in damage to property but also in **loss of life or injury**. Consequently it is imperative that Mariners have a **full** and **complete knowledge** of the buoyage system.

Under the auspices of the International Association of Lighthouse Authorities many countries throughout the world have agreed to the implementation of a uniform coding system of navigational marks. This system is envisaged to be fully implemented in Queensland by the end of 1983.

This International uniform buoyage system is expected to provide **better organised and safer waters** for all who sail them.

Intimate knowledge of buoyage system "A" is a necessity to all users of the water-ways — **it could save your life.**

Description of Buoyage System "A"

Type of Marks

1. **LATERAL** indicates port and starboard hand sides of channels.
2. **CARDINAL** indicates that deeper water lies to the indicated direction relative to the mark i.e. to the north, south, east or west.
3. **ISOLATED DANGER** indicates isolated dangers of limited extent with navigable waters all around them — **but don't pass too close.**
4. **SAFE WATER** indicates that there is navigable water all around and under that position, e.g. mid channel buoy.
5. **SPECIAL** indicates special features e.g. spoil grounds prohibited anchorages, etc.

Lights

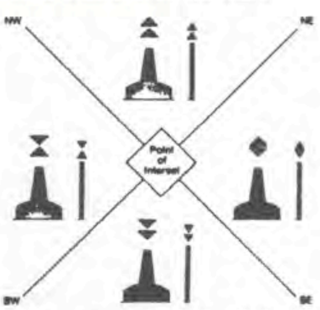
A cardinal mark **exhibits a white light** and its quadrant is distinguished by a specific group of **quick** or **very quick flashes**.

The frequency of the flashes are:

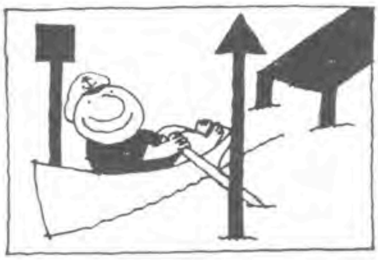
North	— **uninterrupted** flash
East	— **3** flashes in a group
South	— **6** flashes in a group followed by a long flash
West	— **9** flashes in a group

To aid memory associate the number of flashes of each group with that of a **clock face**, three o'clock east, six o'clock south, nine o'clock west.

To ensure that **no confusion** occurs between east, south and west marks a **long flash** immediately follows the **6 flashes of the south mark.**



Note: It is not normal to find Cardinal Marks or Lights in small craft channels.



Lateral Marks

They are usually positioned to define **well established channels**; and indicate port and starboard hand signs of the navigation route into a port. Where there may be any doubt the direction of buoyage may be indicated **on charts** by the symbol:

* **Port mark** — is coloured **red** and the basic shape is a can
* **Starboard mark** — is coloured green and the basic shape is conical
* **By night** — port buoy shows a **red** light
  — starboard buoy shows a **green** light.

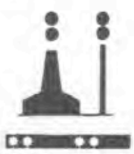
Any rhythm may be used.

Upon entering a port the **port hand mark (red)** should be passed on your vessel's **port side**. Alternatively, when departing a port the **port hand buoy (red)** should be **passed** on your vessel's **starboard side**.

Isolated Danger Mark

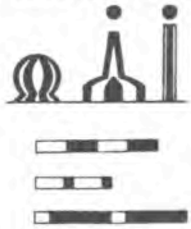
USE	Designates an **isolated danger of limited extent** which has navigable water all around it e.g. an isolated shoal, rock or wreck.
TOPMARK	Two black spheres positioned vertically and clearly separated.
COLOUR	Black with one or more red horizontal bands.
LIGHT	A **white flashing light** showing a group of two flashes.

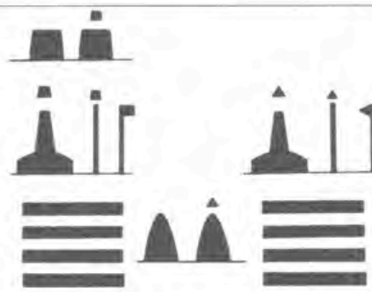
The characteristics may be best remembered by association of **two flashes** with **two spheres** as the topmarks.



Safe Water Marks

USE	Indicates that **there is navigable water** all around the mark, e.g., mid channel or land fall buoy.
COLOUR	Red and white vertical stripes.
TOPMARK	A single red **sphere**.
LIGHTS	Exhibits **a white light**, isophase, occulting, or **single long flash** every 10 seconds. **Single flash** and **a single sphere** association may help in remembering these characteristics.





Cardinal Marks

NAME OF MARKS	A cardinal mark indicates where the **best and safest water may be found**, and is used in conjunction with the **compass**. The Mariner is safe if he passes — (a) North of the north mark (b) East of the east mark (c) South of the south mark (d) West of the west mark
USES	A cardinal mark may indicate — * the **deepest** water in an area * the **safe side** on which to pass a danger and to draw **attention to a feature** in a channel such as a bend, junction or an end of a shoal.
TOP MARKS	Black double cones clearly separated.
COLOURS	**Black and yellow horizontal bands** with position of the black band or bands relative to the respective cardinal points.

North	Topmark points up, black band above yellow band.
East	Topmark points outward, black bands above and below yellow band.
South	Topmark points down, black band below yellow band.
West	Topmark points inward, black band between yellow bands.

Special Marks

USE	Indicates a **special area** or feature such as: **Traffic** separation marks **Spoil** ground marks **Cable** or pipe line marks including outfall pipes

Also to define a **channel within a channel** e.g. a channel for deep draught vessels in a wide estuary where the limits of the channel for normal navigation are marked by red and green lateral buoys.

COLOUR	Yellow.
TOPMARK	When a topmark is carried it takes the form of a **single yellow X**
LIGHT	**It is yellow**, the rhythm may be any, other than those used for the white lights of cardinal, isolated danger and safe water marks.

Remember with the introduction of the IALA Maritime Buoyage System "A" the Wreck Buoy **will no longer exist. It will be substituted by the Isolated Danger, Special Mark** or **Cardinal Mark**

HARBOURS MARINE
Caring for our coast

CHAPTER 5

OUT OF THE CLASSROOM

Purpose

To introduce you to some navigation instruments that are used on vessels that navigate the sea.

Pre-requisite skills

Nil. It may be an idea to organise a visit to a vessel to see at first hand some of these instruments and have a ship's master talk to the class about them.

Objectives

You should be able to recall some of the instruments associated with navigating at sea and state their purposes and shortcomings

Time required

3 hours

Fig 5.1: A large ship requires many navigational aids to bring it safely to port.

On a boat there are many items of navigation equipment that we will discuss throughout this unit. There are many more things to learn if you are going to sea.

Some things to deal with concerning the compass are:	*Some other important pieces of navigation equipment to be dealt with*
Errors of the compass *Error of Variation* *Error of Deviation* *Geographical and magnetic north* *Swinging the compass* *Compass error*	*The sextant* *The Radio Direction Finder* *The Depth Sounder* *Radar* *Decca and Loran* *Gyro Compass set* *Publications such as notices to mariners*

THE SEXTANT

Some mariners think that the sextant is an instrument solely for use with celestial bodies when the vessel is navigating long open stretches of ocean. Experienced navigators use the sextant extensively for navigation close inshore, sighting on shore-based objects.

Because it is a precision instrument it produces a high degree of accuracy, and is generally much easier to use aboard small craft than the hand bearing compass. Probably because of the relative expense of marine sextants, few small craft carry them other than for extended offshore passages. Have someone come to your class and demonstrate a sextant and its correct use.

THE RADIO DIRECTION FINDER

The marine radio has two functions as a navigational aid. It is used to provide time checks for the navigator's clocks or watches.

As well the radio can be adapted for picking up directional signals. These provide bearings for use in plotting the boat's position. Also there are weather reports, normal ship to ship, or ship to shore traffic, emergency uses.

But from the navigator's point of view, the time signal and the RDF signal are the two for immediate use.

RDF stands for Radio Direction Finding and the adaptation of a normal radio receiver for this purpose involves only the fitting of a 'loop' aerial and compass card or pelorus.

Most RDF units are compact and complete in their own right. But any normal receiver can be used providing it can pick up the frequency of the signals and has the loop aerial which can be tuned.

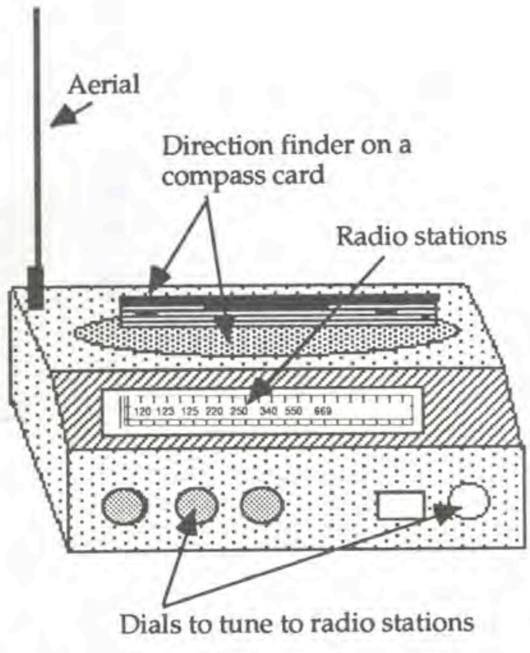


Fig 5.2: A radio direction finder measures the angle to the nearest radio station.

DEPTH SOUNDING

The old 'lead line' type depth sounder still can be used on board small boats. Boat hooks, oars, and just about anything else which will indicate the depth of water under the keel when navigating in shallow water could be used.

A lead line is a length of light line weighted at one end and with depth measurement markings along its length, which is literally bounced on the bottom as the boat passes over it, and the depth of water read off the markings.

The modern depth sounder is an electronic version of the same thing which uses the sonic principle of bouncing a 'pulse' off the bottom.

A transducer fitted to the bottom of the boat transmits an electronic pulse which bounces off the sea bed and is picked up by a small receiver, also in the bottom of the boat.

By measuring the time from transmission to receiving, the sounder records the depth of water under the keel.

The measurement may be indicated in a number of ways, a neon blip on a dial is one commonly in use or a continuous trace on a moving paper another. The latter has the advantage that it traces a record over a period of time, thus drawing a 'picture' of the undulations of the sea bed as the boat passes over it.

These instruments have been developed to a high degree of sophistication and in some cases are sufficiently sensitive to record schools of fish which pass under the boat.

Suppose you wanted to chart a body of water and include depths and obstructions on your chart. First, you would need a map showing the outline of the body of water.

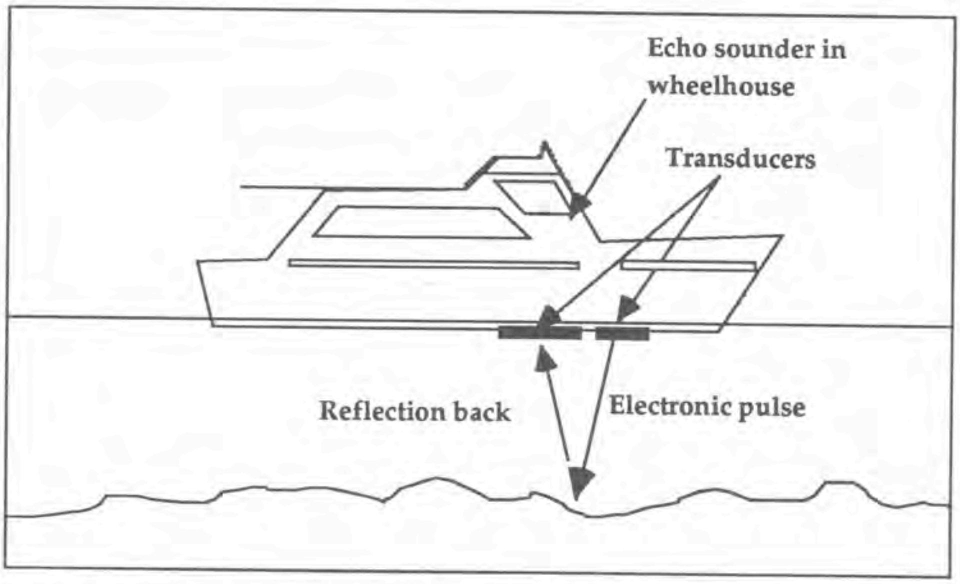


Fig 5.3: A depth sounder measures the distance from the bottom of the keel to the bottom of the ocean floor.

Then you would have to go out on the water to measure the depth at various predetermined locations. By recording the depths at each location on your map, you will be able to construct your chart. This type of chart is called a *BATHYMETRIC CHART* or a chart of depths.

ACTIVITY 5.1 BATHYMETRIC ANALYSIS

You will need:

1. A black box . The black box must be prepared in advance. It is constructed from one half sheet of 3/4 inch chip board . Make the box up to 50 x 75 cm and fill the bottom with bricks, broken blocks and wood scraps. Fill with clean builders' sand. Cover the top of the box with peg board and rule lines of longitude and latitude.
2. Stiff wire - welding rod or coat hanger wire to fit through peg board
3. Metre rule
4. Line to mark track

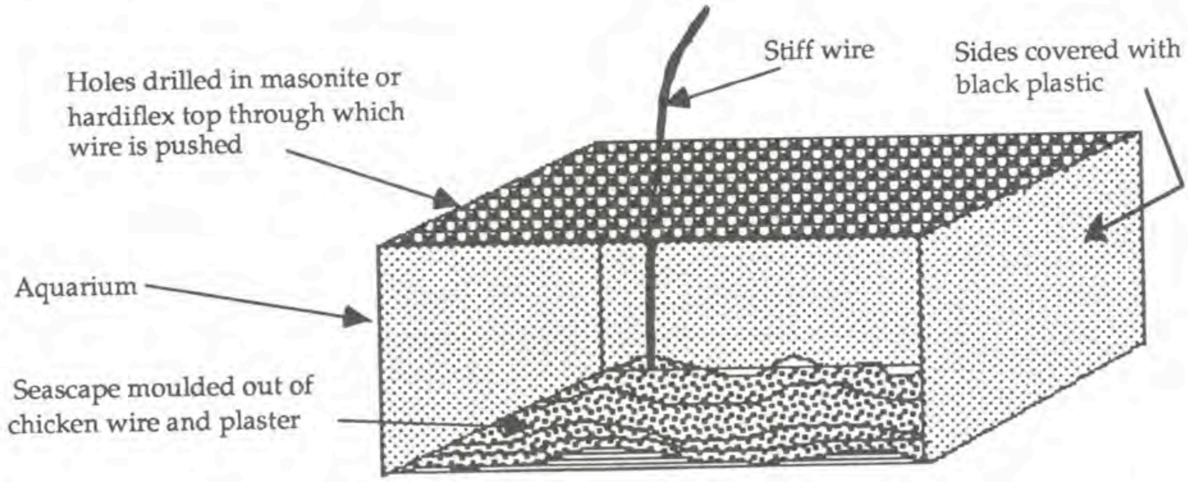


Fig 5.4: A black bathymetric box can be made from an old aquarium, some chicken wire and casting plaster or plaster of paris. **Hint:** Students will have to place a sheet of squared paper over the top to get a soundings grid and the sides will have to be covered

What to do:

1. Use the wire to poke holes through the peg board until it touches the sand.
2. Note the length of the wire and graph the profile of the unseen floor. You may wish to use a toy ship to simulate the exercise.

Questions: Classroom demonstration

Q 1. How does the size of the interval between readings affect accuracy?

Q 2. How can inconsistent features, e.g. isolated peaks, one great depth, be explained?

Q 3. Does one of a few tracks really show the general topography?

Q 4. How important is accurate navigation in sailing the seas? How can Bathymetric Charts be used for navigation?

Q 5. Are accurate charts important in deep ocean water? Explain your answer.

NOTE: This investigation similates the techniques used by oceanographers. It will give you the idea of the difficulty in mapping the unseen ocean bottom accurately.

So remember that bathymetric charts are the results of many soundings and are as accurate as the data collected permits. Soundings are taken by an echo sounder which sends a pulse to the ocean floor and back again. The pulse is sent from a transducer fitted to the bottom of the boat, and the echo is analysed by a small receiver under the keel. By measuring the time interval, the depth of water is computed by the sounder.

RADAR

(Stands for **R**adio **D**etecting **a**nd **R**anging.)

Radar is, perhaps, the best coastal navigation instrument since it eliminates so many of the problems of visual navigation. It is however subject to incorrect readings in strong rain squalls.

It can 'see' in the dark, penetrate fog and mist and combine all the usual coastal navigation plotting systems into one. This enables the navigator to check a boat's progress at regular intervals without leaving the wheelhouse.

Radar works on a similar principle to the depth sounder. An electronic pulse is transmitted from the scanner which 'bounces' back off shore or other objects close by. The 'echo' is picked up by the receiver. As the scanner on top of the wheelhouse rotates through 360 degrees, these echoes are converted into a map-like picture on a cathode tube with the boat as the centre of the picture, and the local scene spread out around a 360 degree horizon.

The set incorporates a method of measuring bearings and distances enabling the navigator to carry out his position plotting. Because of a number of limitations, radar must be used with caution. One of its biggest problems is the tendency of the pulse to 'echo' only off certain objects.

A cliffy coastline, for example, will usually present an excellent picture on the radar screen, whereas a low sandy shoreline may show up only faintly, perhaps not at all. Navigation marks such as buoys or channel indicators may not show up too well on the screen unless they are fitted with radar reflectors. These reflectors increase the strength of the radar echo and create a much stronger 'blip' on the screen.

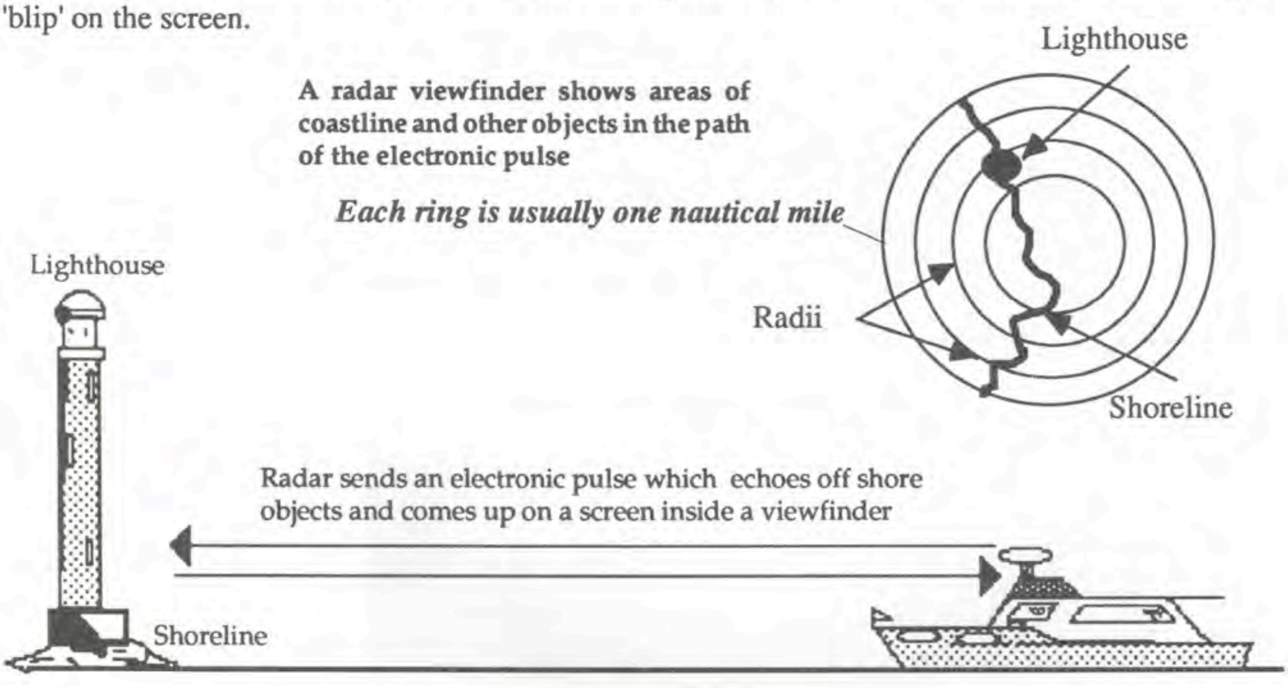


Fig 5.5: Radar bounches back off shore and other objects and the echo is picked up by a receiver.

ERRORS IN THE COMPASS

Any error in a compass can be fatal for a boat.

Therefore a good navigator will keep a constant check on the master compass. Only a few degrees of error can mean the boat is well off course during a night's boating, and may be grounded before anyone is aware that anything is wrong.

Checking a compass for accuracy is therefore vital.

This task is the sole responsibility of the navigator. On most commercial ships the compass is checked every watch (four-hourly intervals) and although this is not entirely necessary on small craft a good check twice a day should be set as standard. Since dawn and dusk are excellent times for a compass check, most yachts follow this procedure.

There are two main sources of error in a boat's compass:-

(a) As a result of some physical damage
This can occur through severe movement of the boat in a seaway causing one of the needles to drop off or in some other way creating damage to the instrument or

(b) An error induced by outside magnetic forces.
Error from outside magnetic influence can be determined and must be allowed for by the navigator when computing his calculations.

ERROR OF VARIATION

This is the error caused by the magnetic and true poles being in different places. It manifests itself in every compass by deflecting the needle away from the *true* north until it is pointing at *magnetic* north.

There may be a difference of up to thirty degrees or more between these poles. This is obviously a factor which must be taken into consideration when steering a course or taking bearings.

Fig 5.6: The deflection of a compass may vary as a vessel progresses across the earth's surface.

The deflection may be to the east or the west of true north, and varies as the boat progresses across the surface of the earth.

However, it is well plotted, and is listed on every chart so that the navigator can be immediately aware of the variation error in his vicinity. Once found, the error is constant for that area, and changes only slowly as the boat progresses.

ERROR OF DEVIATION

This is the deflection of the needle by the magnetic influence of some object on board the boat. The best example is that of placing another magnet, or even a piece of metal, near the compass.

An immediate deflection will be seen. It varies greatly according to the boat itself, the material from which it is constructed, and any magnetic material carried aboard. In the case of fibreglass and timber craft, there is little in the hull structure to cause problems.

But steel and ferro-cement boats can have big problems with deviation because of the magnetic forces of the inbuilt steel. Similarly, any boat with a lot of electrical circuits in the vicinity of the compass can suffer from the magnetic field set up by the electricity.

Electric generators, radios and instruments can cause deviation problems. So obviously a great deal of care is needed if the error is to be avoided or at least reduced to a minimum.

Where the deviation is in the boat structure, as in the case of a steel or ferro-cement hull construction, the compass error must be corrected with small magnets placed around the compass binnacle. This must be done by a professional compass corrector, as great skill is required to make the correct adjustments.

The boat is built lying in the earth's magnetic field and in the course of her construction absorbed the earth's magnetism in much the same way that one induced magnetism into bits of iron by stroking them with magnets when in primary school.

The boat, in effect, becomes one big magnet itself, and the effect on the small magnets of the compass can well be imagined.

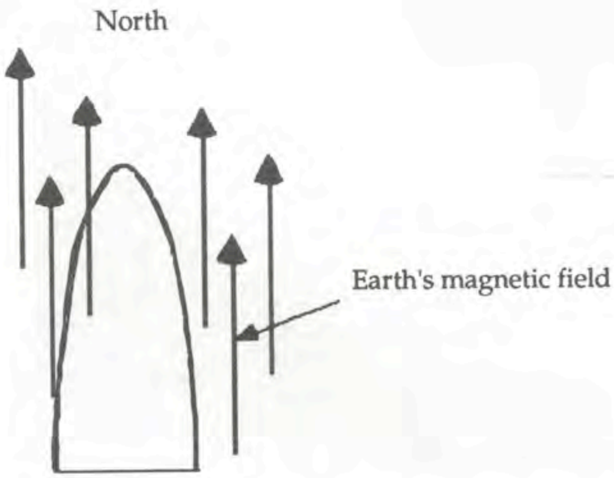


Fig 5.7: A boat moored North - South can become one "big" magnet and hence seriously affect the vessels compass

A boat moored in a north --- south position for a long time should be remoored to face south --- north. This is to correct compass error that can occur because of the earth's magnetic influences. One mariner reported being up to 30° out in his compass because of the error in deviation caused this way.

When fitting out a boat, the problem can be avoided to some extent, by taking care to mount magnetism-inducing equipment at least one metre away, and by keeping all iron metal at a similar distance.

This is not always possible, of course, and most boats experience some form of deviation.

Shielding the compass can be effective and soft iron balls on either side of the instrument may reduce the effect. Trial and error is the only way with this system. Remember, deviation is not constant, but changes each time the boat alters course.

SWINGING THE COMPASS

Variation is a constant factor and can be accounted for in navigational calculations (it is marked in the centre of every compass rose on the chart). Deviation can vary each time the boat has some alteration done to the structure, or even in loading supplies like canned foods. Deviation also varies according to where a ship is heading, since the magnetic field varies over the earth's surface. Deviation therefore is a changing factor and must be considered and checked, each time the boat puts to sea on a new voyage. Compass adjusters - professional people who are trained to check and correct the compass for deviation - are available in most ports of any size to assist navigators as they travel the earth's surface.

Fig 5.8: Large vessels need professional compass adjusters to accurately set their compasses.

CHAPTER 6

THE SMALL SHIPS FORECAST

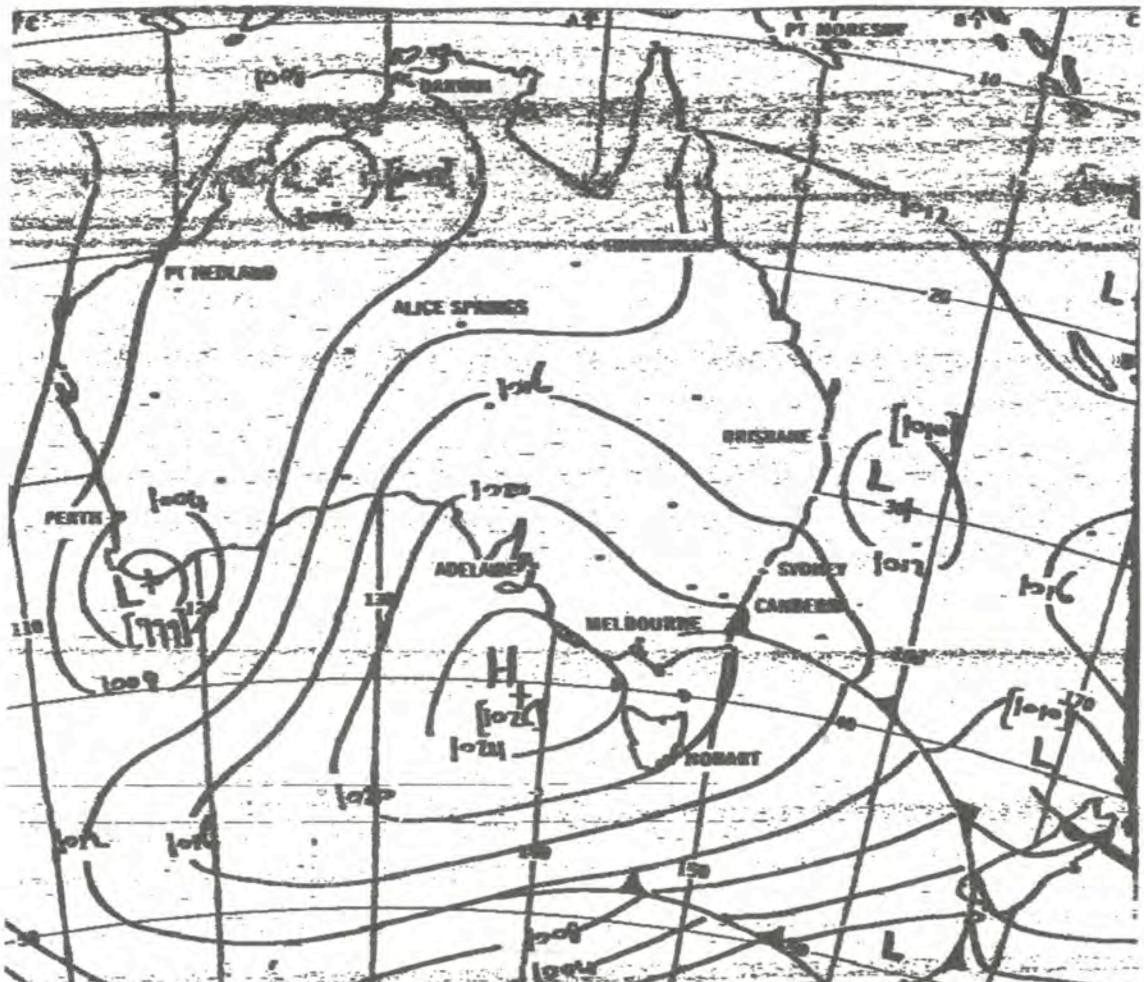


Fig 6.1: A weather fax showing the movement of a high pressure system over Australia. Weather faxes are an invaluable guide to mariners at sea as they can give early warnings of bad weather.

Purpose

To introduce you to some basic ideas about the weather as they apply to local coastal navigation.

Prerequisite skills

A knowledge of your local weather map would be an advantage.

Objectives

You should be able to:

C. Recall the main functions of the structure of the atmosphere
C. Recall the main features of a weather map
P. Interpret the meaning of the following on a weather map: Trough, Front, High, Low, Depression, Isobars, Rainfall, Jet Stream, Millibar
P. Make simple predictions from a location map e.g. cold, hot, windy, humid
S. Use a Thermometer, Barometer and Hydrometer
A. Value the importance of the small ships forecasts for yachtsmen and the boating fraternity in general.
C. Recall 5 cyclone or low pressure warning signals
P. Describe some sea conditions
C Describe the formation, structure, movement of air associated with a cyclone.
A. Be aware of the safety procedures to follow in a cyclone
P. You will be expected to apply the knowledge you have gained in this topic to new situations.

It may be worthwhile doing some simple experiments in the laboratory to demonstrate Condensation and Evaporation. Also there is a need for students to understand a barometer and some simple pressure equipment.

Time required

4 hours

"RED SKY AT NIGHT SAILORS DELIGHT, RED SKY AT DAWN SAILORS MOURN"

For some of you the next time you may see a chart is when you go on an *under 35's cruise* to the South Pacific. You may be confronted with a cruise map like the one in figure 6.2

The South Pacific holds many wonderful islands all of which can be reached by navigation. In Australia also the Coral Islands and Cays that make up our Great Barrier Reef make for wonderful holidays. The people who work there are very much affected by weather conditions. Rough weather can mean a totally different holiday programme to one with calm weather conditions. A good employee will be able to look at and interpret a weather map such as the one shown in figure 6.2 and make plans for the next day's activities.

The planning of snorkelling areas, the type of lunch to be served, the movement of guests to and from ships or moorings, the types of games that can be played all demand a knowledge of the weather. So let us have a look at what our daily weather pattern reveals.

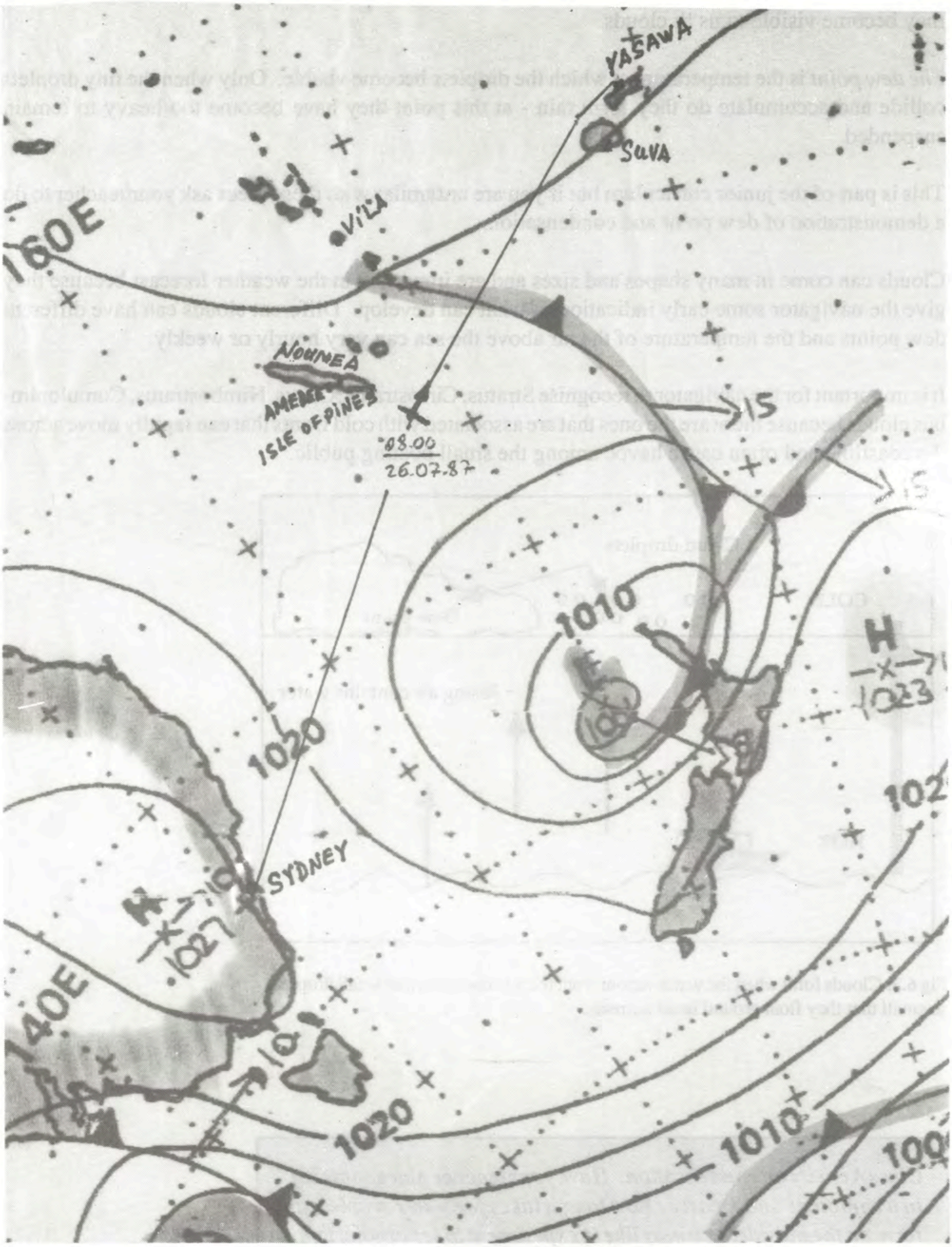


Fig 6.2: Part of a cruise chart shown to guests on an under 35's South Pacific cruise to Fiji and Noumea. The low pressure system marked can greatly affect the day's activities at Yasawa in Fiji when the ship arrives.

CLOUDS

Clouds form when the water vapour in the air condenses into small droplets, so small that they float around in the air currents. If large enough numbers of these droplets come together in one area, they may become visible to us as clouds.

The dew point is the temperature at which the droplets become visible. Only when the tiny droplets collide and accumulate do they form rain - at this point they have become too heavy to remain suspended.

This is part of the junior curriculum but if you are unfamilar with these ideas ask your teacher to do a demonstration of dew point and condensation.

Clouds can come in many shapes and sizes and are important in the weather forecast because they give the navigator some early indication of what can develop. Different clouds can have different dew points and the temperature of the air above the sea can vary hourly or weekly.

It is important for the navigator to recognise Stratus, Cirrostratus, Cirrus, Nimbostratus, Cumulonimbus clouds because these are the ones that are associated with cold fronts that can rapidly move across the coastline and often cause havoc among the small boating public.

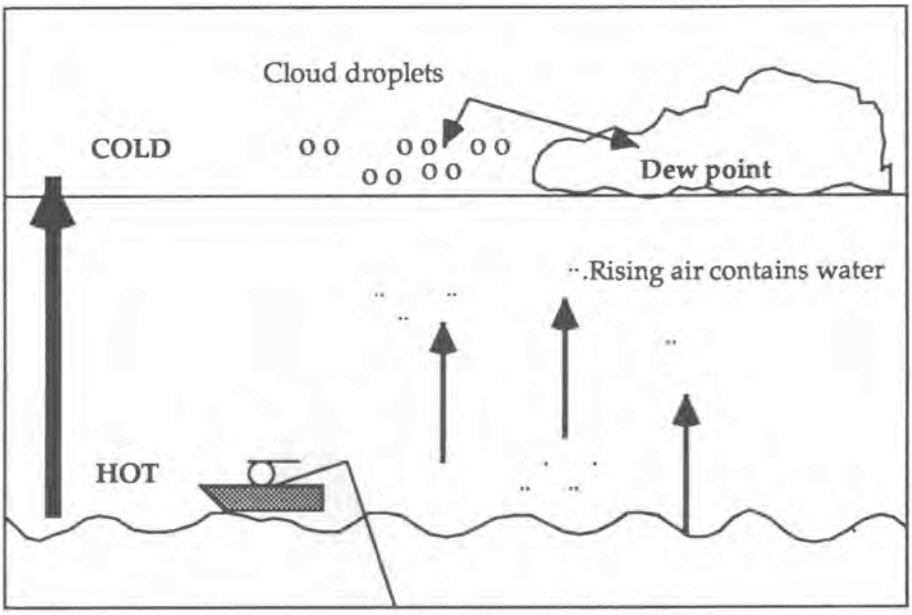


Fig 6.3: Clouds form when the water vapour from the air condenses into small droplets, so small that they float around in air currents.

Class Activity on condensation: Have your teacher place some ice in a container and measure how long it takes for water droplets to form on the outside. You may like to experiment to see at what temperature condensation occurs.

FRONTS

A front is the boundary between a cold air mass and a hot air mass and is usually associated with gusty winds and rain.

You can see the onset of a front with the cloud formation. It is important therefore to recognise the importance in the issuing of a weather forecast.

Australia is primarily affected by cold fronts which move in an easterly direction from Western Australia. A navigator should take careful note of these as they will see the onset of gusty winds and high seas.

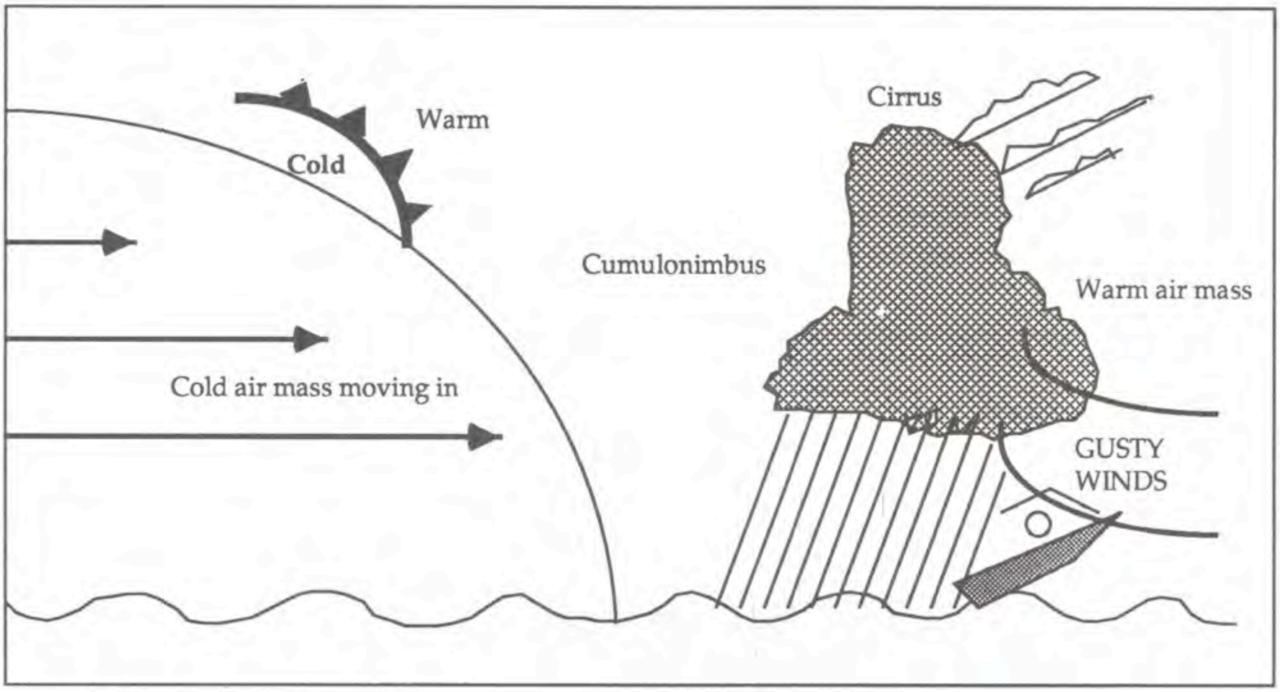


Fig 6.4: A cold front.

Warm fronts are more common in the northern hemisphere but still can occur in Australia. Can you spot the differences between fronts by comparing the diagram below with the cold front above.

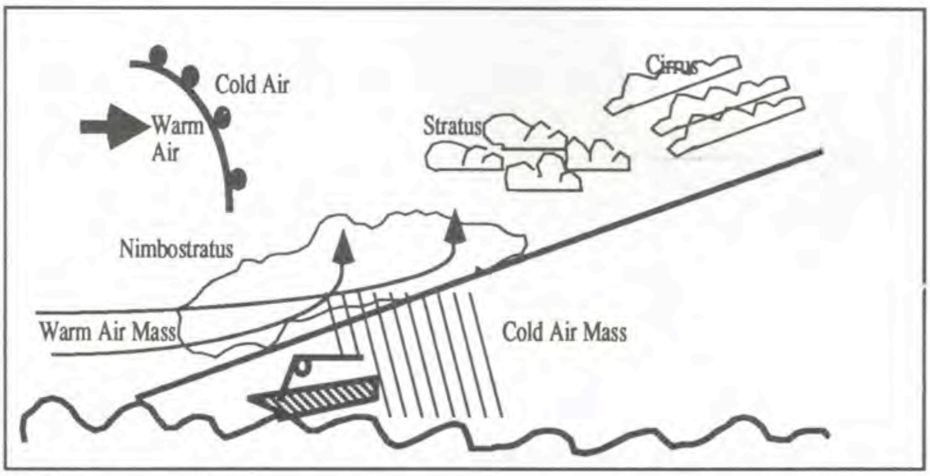


Fig 6.5: A warm front.

THE WEATHER FORECAST

A weather report will always end up with a forecast for small ships. Navigators should always listen to the approach of fronts or unusual conditions.

Careful attention to the weather forecast can make the difference between an enjoyable afternoon or an expensive salvage claim, between winning or losing a sailing race, between a fast and exhilarating beat across the bay or a long and tedious one, and between a relaxing afternoon afloat and the depressing moans of a wet, seasick and half frozen crew.

Just listening to the forecast is not enough. Listening habits are such that most people hear what they want to hear anyway.

It is essential to listen and take note of what is said. If the details are long you should write them down.

Finally, it takes a lot of good common sense to plan not to go out on a doubtful forecast unless you know the local area very well.

There is an old tale that is worth repeating:

There are old sailors and bold sailors
*but there are **NO OLD BOLD SAILORS.***

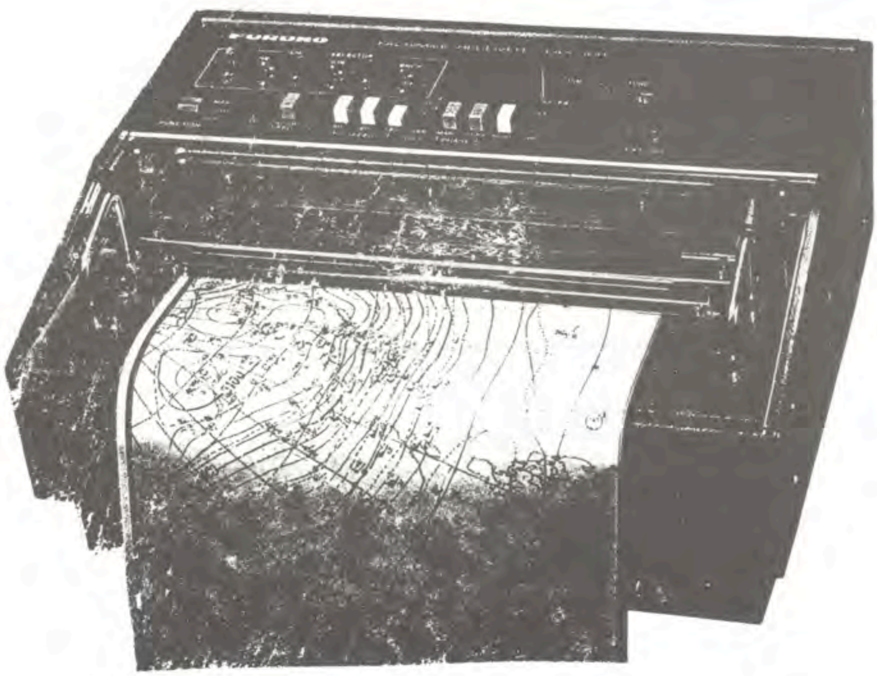


Fig 6.6: A weather fax is used to produce a weather map on which a mariner bases many important decisions.

Fig 6.7: The weather bureau uses satellite information to plot clouds. From these and ground information from weather stations all around Australia, it can draw weather maps and issue weather forecasts.

CYCLONE OR LOW PRESSURE WARNINGS

In the tropics cyclones occur each year in the summer months, and in the southern states, low pressure systems stream across the continent with great speed. There are some signs that the navigator needs to look for. These are summarised below and on the pages that follow:

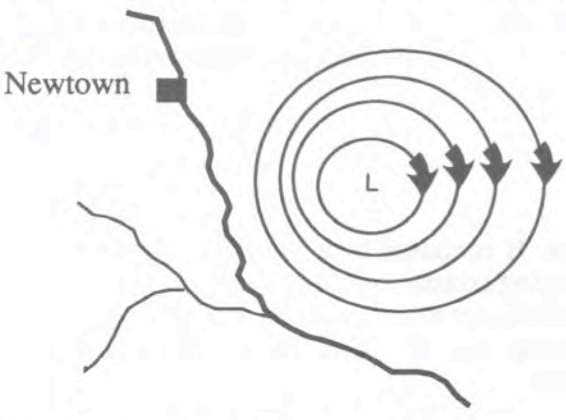


Fig 6.8: What a cyclone looks like on a weather map

What causes a cyclone?

A cyclone is really a complex low pressure system with high winds and driving rain. A combination of weather factors cause this. Summer sun beating on the warm ocean evaporates water, creating deep layers of moist air. The uplift of this moist air in the centre of a low cools it, causing the intense rain characteristics of tropical cyclones.

High in the atmosphere, the rising air spirals outwards, removing air faster than it flows inwards at low levels. The result is a falling barometric pressure.

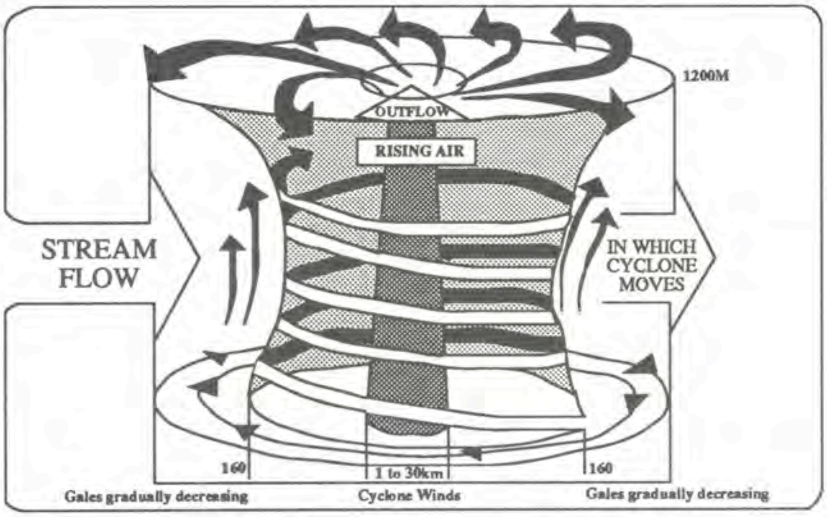


Fig 6.9: The anatomy of a cyclone.

What are the signs of an approaching cyclone?

1. Barometer falling fast, to an exceptionally low reading.
2. A marked heavy ground swell. This is quite different from normal swell conditions.
3. A distinctly lurid appearance about the sky in the direction of the storm.
4. As the storm approaches, there is a marked shift in the direction of the winds as well as increasing wind force.
5. A distinctly howling wind - these winds are quite distinctive.

Where do cyclones hit?

The main target of cyclones in Australia is the northern half of the coastline between November and April. But this is no iron-clad rule. Even in the more southern states, cyclones can strike at other times as well.

What is a storm surge?

A storm surge is often associated with a cyclone. It is caused by a combination of low pressure and cyclone winds piling sea water up against a sloping coastal shelf to produce a tide above predicted level. Water near the coast can rise because there is not as much pressure on the water compared to a high pressure situation. This causes the water to rise. Winds also blowing for a long time in the one direction also pile up the water on the coast.

The rising water floods inland over low lying areas normally above tidal influence. It can cause massive beach erosion and thousands of dollars damage to coastal resorts.

CYCLONE WARNINGS

In many Pacific countries there is a cyclone season. Cyclone warnings are given over the radio. The warning message contains information on the severity of the cyclone in terms of winds and tides.

The AMP society of Australia produced an excellent brochure on cyclones. The text is reproduced below with thanks:-

"As well as indicating the expected maximum wind gusts near the centre of the cyclone, the warning will usually indicate the strength of the maximum gusts expected over particular areas in any of the following terms:

* Gales with gusts above 95km/h
* Destructive winds with gusts above 130km/h
* Very destructive winds with gusts above 180km/h.

The warning may mention above normal tides. The effect in terms of the risk of flooding at the coast will be described as follows:

* Abnormally high tides could cause minor flooding....
* Abnormally high tides could cause serious flooding....
* Dangerously high tides could cause extensive flooding...

If evacuation of waterfront areas becomes necessary, additional messages from police or emergency officials will say who should move and will give details of evacuation shelters.

Emergency/evacuation kits

Emergency Kit
(hold ready in house)

* Battery operated transistor radio and torch with fresh batteries. Tinned food. Water in containers. Candles. Matches. Essential clothing.
* Emergency self-contained cooking gear.
* First aid kit. Essential medicines.

Evacuation Kit
(carried in small bags)

* Warm utility clothing (jeans, skivvies, etc).
* Wear strong clothing to protect against cuts from debris.
* Strong footwear (not thongs) should be worn to protect against cut feet.

Many of these lifesaving precautions can be taken immediately. Do them now and be prepared.

What to do if the warning system says local evacuation

1. Lock up dwelling, switch off electricity, gas etc (if applicable)
2. Take the emergency and evacuation kit
3. Follow advice given.
4. Heed official warnings... they are not given lightly!

What to do if you don't have time to evacuate (or if you know it is unsafe to do so)

If you are unable to evacuate your house, stay inside, remain calm, secure your house, your furniture, and yourselves as set out in the preceding paragraphs. Stay tuned to your transistor radio.

Stay tuned: Stay alive

In Australia tropical cyclone warning centres at major cities keep around the clock watch during the cyclone season.

Their information is gathered from a variety of sources such as land reporting stations, offshore automatic weather stations, weather satellite cloud photographs, balloon borne weather instruments, radar units and from ship or aircraft reports.

If a tropical cyclone appears likely or a cyclone is detected, the Bureau issues either a cyclone watch, a cyclone warning, or a flash cyclone warning.

A cyclone watch means a cyclone is approaching but is not expected in your locality for the next 24 hours. A cyclone warning means a cyclone is expected to threaten your community within 24 hours. A flash cyclone warning is the first warning issued for an area. It is also issued when major changes to previous warnings are necessary.

In all cases, rule number one is: keep tuned to your transistor radio and follow implicitly instructions given. Police and emergency officials will also give warnings.

How to be well prepared before the cyclone season

As with other natural disasters, being prepared and well armed with knowledge before the event is by far the most important thing. You can minimise the risk by following these simple measures:

* Be sure that your transistor radio is working and that you have fresh spare batteries.
* Check that your house is sound, particularly the roof.
* Clear your property of loose sheet iron, loosely anchored rain water tanks, and other potential missiles.
* Know your community disaster plan.
* In case of a storm surge warning, know your nearest safe high areas.
* Collect tinned food, water containers, emergency lighting, candles, essential clothing, first aid kit, medicines.

When the cyclone comes

* Keep calm, stay inside.
* Shelter in the strongest part of the house. (Probably the bathroom, internal toilet or central hallway.)
* If the house starts to break up, protect yourself with mattress and blankets.
* Anchor yourself to a strong fixture such as water pipes, or get under a strong table or bed.

Beware the 'eye' of the cyclone

The winds in a cyclone whirl clockwise around a 'calm' eye. This eye is something less than 10km in diameter (though it may exceed 30km across). When the wind drops, there is no rain and often very little cloud. You must be aware of this temporary lull, for when it has passed, the wind will return with battering force, probably from another direction. Stay protected. Do not go outdoors.

After the cyclone has abated

* Keep listening to your radio.
* Don't go outside until advised officially or you are positive the cyclone has passed.
* If you had to evacuate, don't go home until advised. Use the route recommended.
* Don't panic
* Don't stay in the open or go sightseeing.
* Above all, don't ignore warnings!"

PRACTICAL EXERCISES

1. Obtain a Thermometer, Barometer, Weather Vane, Psychrometer (wet and dry Bulb Hydrometer), and learn to take measurements.
2. Make up a small ships forecast.
3. Go to a Radio Station and see how forecasts come in from the Weather Bureau and are broadcast.

STATES OF THE SEA

These can be summarised in the table below:

Forecast as heard over radio	Height of Waves (m)	Approximate condition of the sea and approximate beaufort scale of wind force
5 to 10 knots wind felt on the face	0 - .5 m	Small waves, direction of smoke shown, **Force 3**
10 -15 knots	.5 - 1.5 m	Fresh breeze, moderate waves, taking a long form, many white horses, chance of spray **Force 4**
15 -20 knots	1.5 - 2 m	Strong breeze, many white horses, spray uncomfortable ride in small boat **Force 5**
20 - 25 knots	2 - 3 m	Very strong winds, large waves begin to form, very uncomfortable and possibly unsafe in small boat. Indication of a front moving through or low pressure system **Force 6**
25 - 30 knots	3 - 3.5 m	Near gale, sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind. Very unsafe sea for inexperienced. **Force 7**
30 - 35 knots	3.5 - 4 m	Gale warning. Moderately high waves of greater length, low pressure system or cyclonic seas **Force 8**
over 35 knots	Over 4 m	Not the type of sea to be caught in, in fact tragedies occur in seas of this magnitude. **Force 9**

Fig 6.10: The Beaufort Wind Scale

STUDY ASSIGNMENTS

1. Why are the Trade Winds important?
2. Of what significance are the DOLDRUMS, WESTERLIES to mariners?
3. Make a poster of the various cloud types.
4. What is the Marine Operations Centre in Canberra? What role does it play in Maritime emergencies? Write to them and see what publications they have.
5. Distinguish between Cyclones, Hurricanes and Typhoons.
6. Distinguish between Tornadoes, Willy-Willies and Water-spouts.
7. Distinguish between Troughs and Ridges.
8. What is a Line Squall?

In 1985, the Department of Education's Curriculum Branch set out to produce a series of publications to assist teachers and their students interpret a new syllabus based on criteria based assessment. One of the units dealt with weather and the following pages have been reproduced from the booklet called, "Planet Earth". Copies are in each school, and teachers should look for the series because they give an indication of the new levels of achievement in the Queensland system.

This assignment is based on the collection and analysis of weather maps over a number of days.

Either
Collect a series of weather maps and draw up a table of corresponding sea conditions

or
Prepare a seminar based on the suggestions given for the overlays for the overhead projector

or
Collect a series of weather maps and make a series of predictions for a town 100 kilometers from your school. You may like to use the school phone to check on your predictions.

TITLE: READING WEATHER MAPS

CONTENT:

DYNAMIC EARTH	Earth Forces	
	Weather	✓
	Weathering and Erosion	

FOCUS:

KNOWLEDGE	Acquis-ition	Concept	✓
		Rule	
	Use		
PROCESS	Experimental		
	Analytical		✓
SKILL			
ATTITUDE			

FORMAT:

STUDENT USE	Pencil-paper	
	Equipment/field	
STIMULUS AND SUGGESTION		
TEACHER OUTLINE		✓

LEVEL:

SOUND	✓
HA → VHA	

Reading Weather Maps

A Class Activity

After this activity students should be able to:

* observe the daily change in the weather pattern as recorded on weather maps
* use weather maps to determine wind speed and direction
* infer that wind speed is high when isobar lines are close together
* infer a general west to east movement of pressure systems
* use weather maps to make predictions of local wind speed and direction
* hypothesise that winds blow in a clockwise direction around low pressure systems and in an anticlockwise direction around high pressure systems

Part A : Movement of Pressure Systems

* Have students collect weather maps from newspapers for five consecutive days and paste them in order in a note book or on a sheet of cardboard.
* You may find it useful to make daily OHP transparencies of these weather maps as shown in the diagrams on page 84.
* Once the maps have been collected, refer the students to the first one in the series. If you have made the suggested transparencies, project the outline of Australia and the first overlay onto the screen.
* Explain that a weather map shows the distribution of atmospheric pressure over an area by means of a series of lines called 'isobars'. Define an isobar as a line joining places of equal atmospheric pressure, corrected to sea level. (Discuss why readings are corrected to sea level. Point out that it is necssary to do this for comparison, because air pressure decreases with height).
* The next step is to use the sequence of weather maps to track the daily movement of a pressure system. Point out a pressure system near Western Australia and have the students find it on their first map. (The high pressure system marked in the diagrams would be a good one to pick since its movement on subsequent maps shows the general west to east movement of pressure systems).
* Now have the students look at the second map in the series and find the same weather feature. (Replace Monday's overlay on the OHP with Tuesday's.)
* Discuss the direction of movement of the pressure system.
* Have the students find the same weather feature on subsequent maps and note again the direction of its movement.
* Ask them to find other weather features on their series of maps which also display this general west to east movement.

Part B: Wind Direction and Speed

Draw the students' attention to the wind symbols, usually included in a legend at the bottom of each weather map.

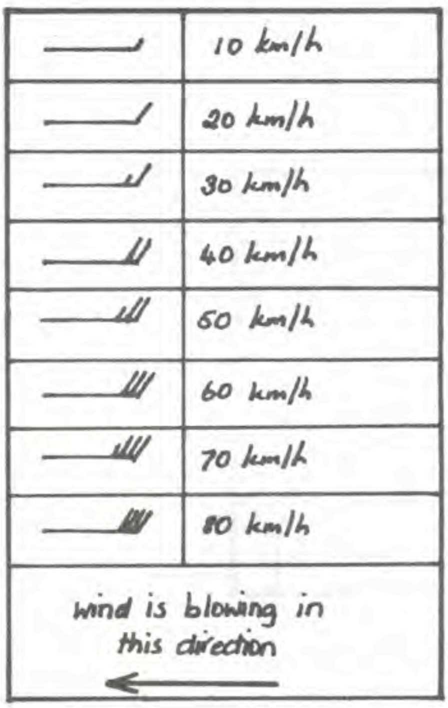


Fig 6.11: Wind Scales

* Have them find a place marked calm on one of their maps.
* Point out to the class that the long line of a wind symbol points in the direction the wind is blowing while the tail indicates the speed of the wind.
* On the map, select a location where the wind speed is high and have students compare the isobars near this location with those close to a calm location. From their observations students should infer that wind speed is high when isobars are close together.
* On one of the weather maps select a low pressure system on which wind symbols can easily be recognized. You may wish to display the map outline and corresponding isobar overlay on the OHP. Have the students describe the wind direction about this low pressure system. They should observe that the wind moves in a clockwise direction about the low pressure system.
* Have the students check the wind direction around other low pressure systems on the same map and then on the other maps.
* From their observations lead students to formulate the hypothesis that winds always blow in a clockwise direction around a low pressure system.
* Discuss with the class how this hypothesis could be tested. One way is to collect as many different weather maps as possible and have the students check each of the lows.
* A similar hypothesis is possible for the direction winds circulate around a high pressure system. This time, however, the wind moves in an anticlockwise direction.

Part C: Predicting Wind Direction and Speed

From an analysis of weather maps students should have now found that:

(a) pressure systems move from west to east;
(b) winds move in a clockwise direction about a low pressure system;
(c) winds move in an anticlockwise direction about a high pressure system; and
(d) winds are strong when isobar lines are close together.

These four pieces of information can now be used in conjunction with a current weather map to make wind speed and direction predictions.

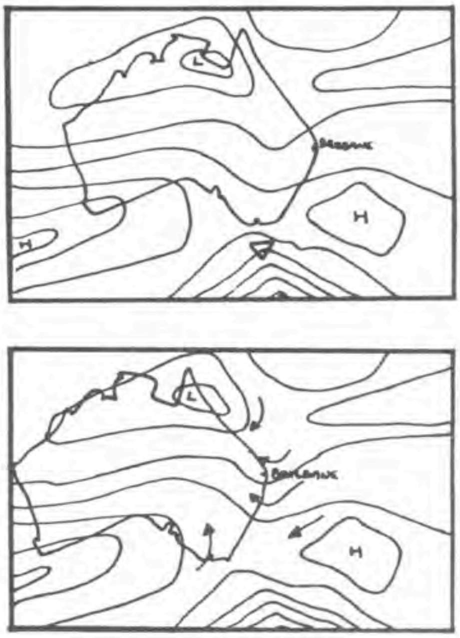


Fig 6.12: Example 1

1. Note the pressure system close to your location. (If you live in Brisbane, for example, the important feature is the 'high' in the Tasman Sea).

2. Winds circulate in an anticlockwise direction around this high so in Brisbane the winds should be from the north-east. This can easily be checked by direct observation.

3. The isobars are not close together so the winds are not strong.

4. To predict wind direction and speed for the next day it is first necessary to imagine that the pressure systems have moved eastwards. (Note that it takes a pressure system about five days to cross Australia. Refer to the high on the OHP transparency isobar overlays). The predicted map would be like this one:

5. From this map it is possible to predict the wind speed and direction for the following day. Winds will come from the south-east and will remain about the same strength.

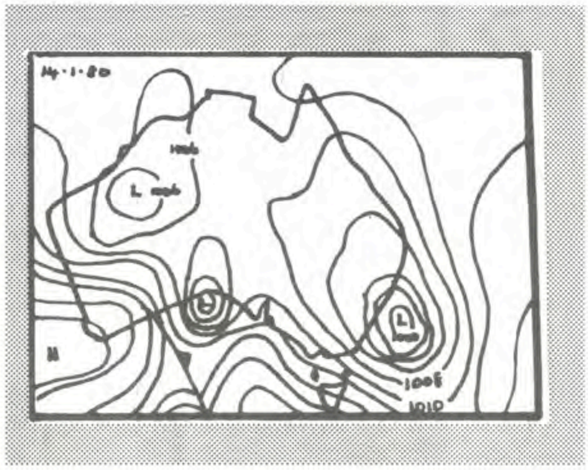
Fig 6.13: Example 2

Winds circulating around the 'high' are strong north-westerlies in Brisbane. Sometime in the next 24 hours, the cold front will pass through Brisbane and in doing so will cause winds to ease in strength and blow from the south-west.

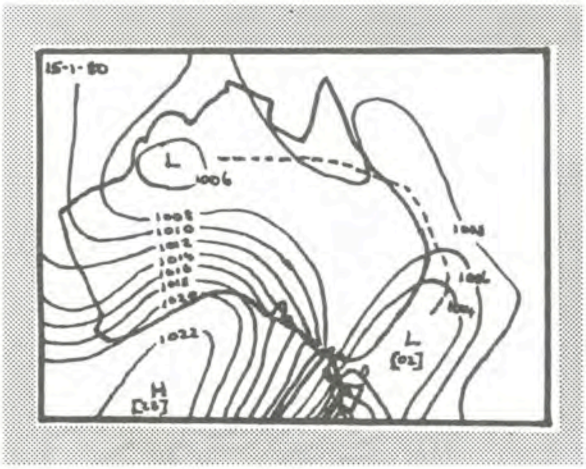
Encourage the students to use weather maps to predict wind direction and speed for the next day.

These figures show what a collection of weather maps look like. Predict the state of the sea for the week.

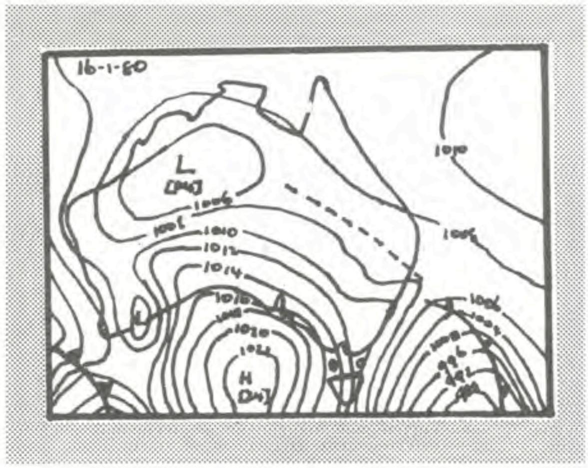
Based on an original idea by the Curriculum Branch, Department of Education, Queensland.



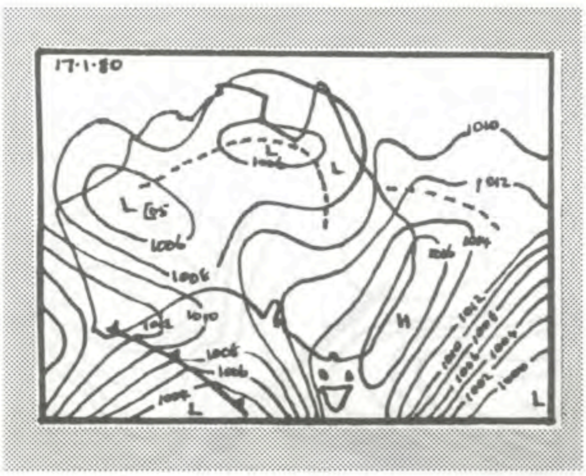
Monday



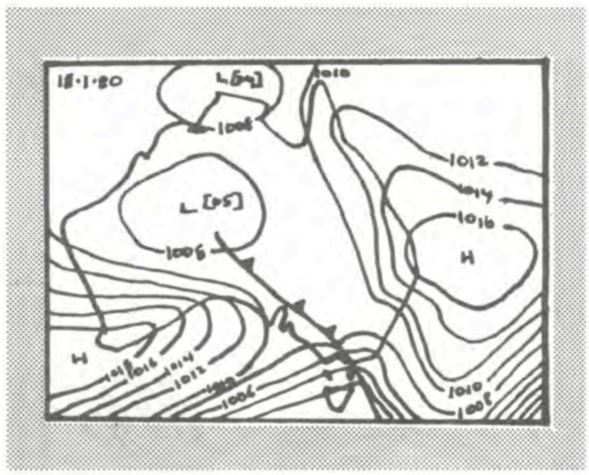
Tuesday



Wednesday



Thursday



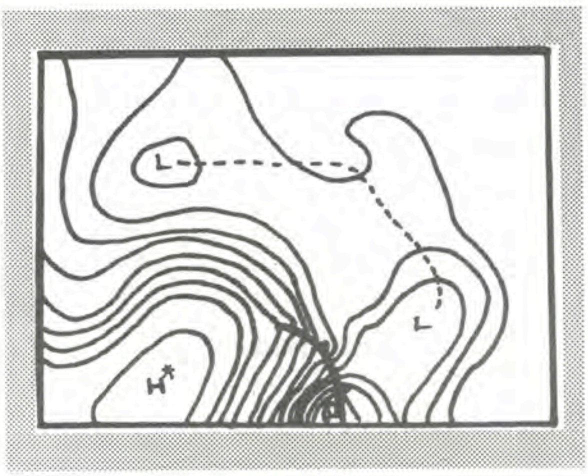
Friday

Fig 6.14: Consecutive weather maps from a newspaper

The figures below show what a collection of overhead transparencies would look like drawn from the weather maps collected for a week. Illustrations supplied courtesy Curriculum Branch, Department of Education, Queensland.

Overhead transparency 1

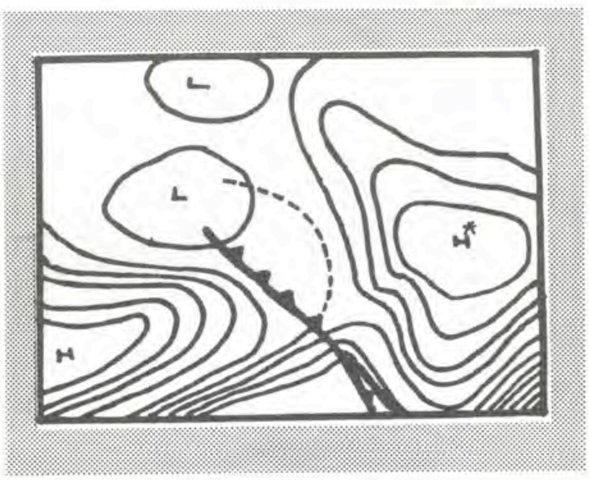
Transparency 2
Monday Isobar overlay



Transparency 3
Tuesday Isobar overlay

Transparency 3
Wednesday Isobar overlay

Transparency 3
Thursday Isobar overlay



Transparency 3
Friday Isobar overlay

Fig 6.15: Overhead transparency overlays of isobars

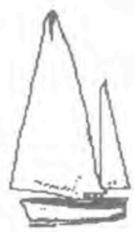
Use the pages and graphics in the next few pages to make up your own worksheets and students contracts.

NAVIGATION CONTRACT

COPYRIGHT FREE PAGES

The following exercises are to be completed as part of this term's assessment.

Activity 1:	Your local chart	/	Due date...............
Activity 2:	Using a compass. Skills mark	/	Due date...............
Activity 3:	Using parallel rules. Skills mark...	/	Due date...............
Activity 4:	Course bearings from your local chart	/	Due date...............
Activity 5:	Hypothetical Bay		
	Exercise 1 Chart features	/	
	Exercise 2 Latitude and longitude	/	
	Exercise 3 Nautical mile	/	
	Exercise 4 Safe navigable distances	/	
	Exercise 5 Distance, speed and time	/	
	Exercise 6 Going places	/	
	Exercise 7 Pilotage(Cardinal system) ...	/	
	Exercise 8 Pilotage(Lateral system)	/	
	Exercise 9 What's your position?	/	Due date...............
Activity 6:	Study of a weather map	/	Due date..............

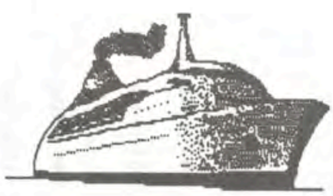


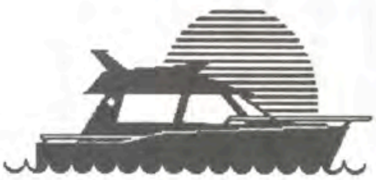
Student's agreement:-

I agree to do the following activities and have noted the due dates in my diary, and agree to hand them in on the set times.

....
Student's signature

Teacher's comment:





WORKSHEET 1: Student's Name:- ______________________

ACTIVITY 1: YOUR LOCAL CHART

1. Make a list in the spaces below of as many chart features which you would not find on a map:

____
____
____
____
____

2. In the space below draw each of these symbols and suggest possible reasons for them.

Symbol	Possible meaning

Note the key symbols such as those used for reefs, soundings and lights and suggest possible reasons for the inclusion of these in the chart of the local area.

Answers to questions:-

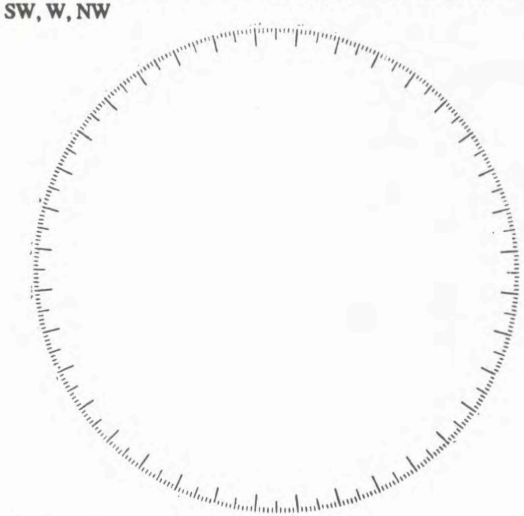
1. What is the deepest section of water on the chart? ____________
2. What is the most northerly point on the chart? ____________
3. Why does a chart need latitude and longitude? ____________
____
4. What date was the chart prepared? ____________
5. Is there a scale on the chart and if so what scale is used? ____________
6. What are the main shipping lights nearest the local port? ____________
____
7. What is the main degree of latitude and longitude? ____________
8. Is the chart in fathoms or metres? ____________

WORKSHEET 2: Student's Name:- ______________________

ACTIVITY 2: USING A HANDBEARING COMPASS

PART A: THE POINTS OF A COMPASS

1. Starting at the top **inside of the circle**, mark in 0° to indicate North, and then 10, 20, 30 ..... by using the protractor.
2. Now on the **outside of the circle**, mark in the following points of the compass:- N, NE, E, SE, S, SW, W, NW



PART B: TAKING A BEARING

Complete the table below by taking 6 bearings from various locations around your school or classroom. E.g. From your desk to the big tree outside: 20°. You are to be within 5° accuracy.

Bearing from	Bearing to	Bearing °

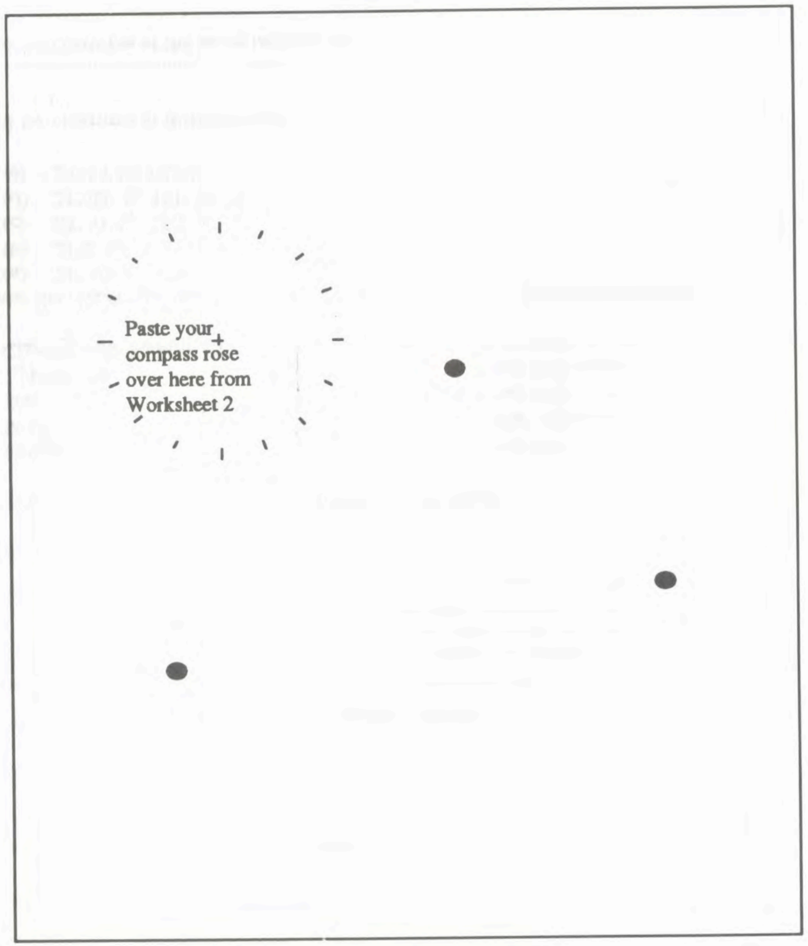
Why are the bearings taken by you different from those taken by other people in the class?

WORKSHEET 3: Student's Name:- ________________________________

ACTIVITY 3: USING PARALLEL RULES

Use your homemade parallel rules to record the following bearings:

From A to B .... From B to C .... From A to C ....



WORKSHEET 4: Student's Name:- ________________________________

ACTIVITY 4: COURSE BEARING CALCULATIONS

Use your homemade parallel rules to record the following course bearings:

Note the compass variation here as....................°.........

Remember if the *Error is east, the Compass is least* so to compute a compass course from a true bearing you subtract.

Course from to	True bearing	Compass course to steer

Working space:-

WORKSHEET 5: Student's Name:- ______________________

ACTIVITY 5: HYPOTHETICAL BAY

Use the copy of Hypothetical Bay to answer the following questions:-

Exercise 1 Questions:

List 10 features on Hypothetical Bay not normally found on a map

__________________ __________________
__________________ __________________
__________________ __________________
__________________ __________________
__________________ __________________

Exercise 2: Questions

1. Find the latitude and longitude of the following points:

(a) Gregory River Light	Latitude..................	Longitude ....
(b) Susan's Light	Latitude..................	Longitude ....
(c) Tony's Light	Latitude..................	Longitude ....
(d) Lyle Wreck	Latitude..................	Longitude ....
(e) Claridgeville Fishing Club	Latitude..................	Longitude ....

2. Name the charted features at the following positions of latitude and longitude
   - (a) 24° 10' S, 151° 53' E ....
   - (b) 24°2' S, 152° 07' E ....
   - (c) 23° 51' S, 152° 07' E ....
   - (d) 24° 03' S, 151° 56' E ....
   - (e) 23° 54' S, 152° 01' E ....

3. Find two features at different latitudes but the same longitude.

....

4. Find two features at the same latitude but at different longitudes.

....

Exercise 3: Nautical mile questions:

What is the distance between the following points:

(a) Gregory River Light and the Fairway Beacon ....

(b) The Fairway Beacon and Trent's Light..............................

(c) Gregory River Light and Susan's Light ....

(d) Tony's Light and North Reef Light ....

Exercise 4 Questions:

What is the safest navigable distance between the following chart features:

(a) Fairway Beacon and Dave's Light __________

(b) Susan's Light and Kev's Light __________

(c) The Clubhouse and the southern tip of North Reef __________

(d) Claridgeville Fishing Club and the Deep Hole __________

Exercise 5 Questions :

1. Distance

(a) How far can I travel in 10 hours if I am travelling at 9 knots ? __________

(b) How far can I travel in 6 hours at a constant speed of 4 knots __________

(c) For 2 hours I travel at 10 knots, and for the next 3 my boat can only make 5 knots. How far have I travelled ? __________

2. Speed

(a) My boat travels 10 Nm in two hours. How fast did she go ? __________

(b) I left harbour at 7am and travelled 5 Nm till 10am. How well did my speed boat perform ? __________

(c) If I set out in my sailing boat at 10.30 am and reached my destination at 2.00pm after travelling 35 Nm, what was my average speed for the trip ? __________

3. Time

(a) How long did it take a mariner to travel 20Nm at an average speed of 5 knots ? __________

(b) Your sailing boat is travelling at 4 knots and your navigator predicts 32 Nm to go. How may hours will it take to reach your destination ? __________

Working:-

Exercise 6: Questions

1. What is the magnetic variation for the chart ? _ _ _ _ _ _ _ _

2. What are the True and Magnetic bearings from:	True	Magnetic
(a) Tony's Light to North Reef Light		
(b) The Fairway Beacon to Sue's Peak		
(c) Tony's Light to Trent's Light		
(d) John's Light to the Water Tower		
(e) Gregory River Light to Trent's Light		

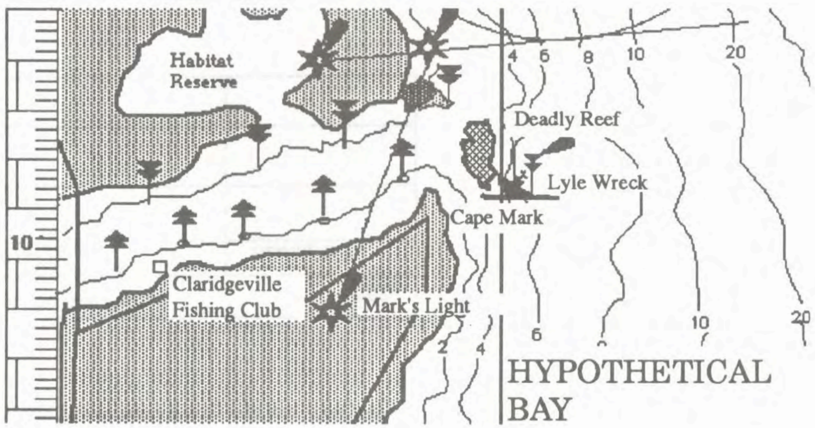
3. By what amount does this variation vary annually?

4. What will be the variation in 1988 ? _ _ _ _ _ _ _ _ _ _ _ _ _

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _

Exercise 7 Questions:

Q1. Name the cardinal marks in Derek's River
Q2. How deep is the water in which these marks stand..................
Q3. You wish to pilot your way into Claridgeville Fishing Club from a latitude 24° 11'S, 152°01'E. Mark on the chart your proposed course avoiding all water below 2 metres



Exercise 8 Questions:

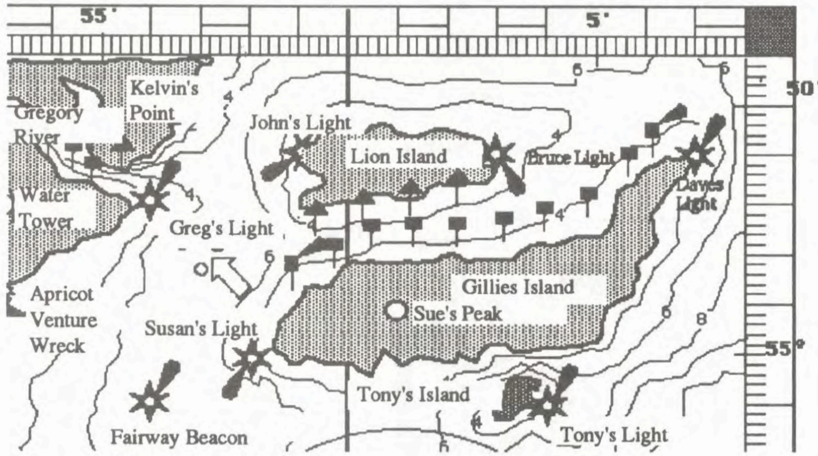
Q1. How many starboard markers are there in Gregory River?.....................

Q2. Mark a safe course down the channel between Gillies and Lions Islands.

Q3. You are leaving port and see this marker.
Which side do you pass and why?

_ _

_ _



Exercise 9: What's your position?

Position 1:

Bearings are: To Trent's Light 235°C, to Tony's Light 305°C, To North Reef Light 160°C

Position 2:

Bearings are: To North Reef Light 95°C, To Trent's Light 155°C, To Sue's Peak, 45°

Position 3:

Bearings are: To Gregory River Light 255°C, To Sue's Peak, 120°C, To Trent's Light 180°C

EXCURSION WORKSHEET
(This page is copyright free so make a copy and take it on your field trip)

WORKSHEET 1 Position fixing		
Bearing from	Bearings to	Bearing in °
Boat		
Boat		
Boat		

WORKSHEET 2 Underway

Days Log:__________ Date:________

WORKSHEET 3: Navigation marks and their meanings

In the spaces below draw and note the colour of the shapes of as many navigation marks as you can see and in the space below write the meanings

Answers Chapter 3

Exercise 1 Hypothetical Bay

Soundings, a compass rose, latitude, longitude, wrecks, lights, capes, points, mangrove swamps, beacons. e.g: The Deep Hole, North Reef, Cape Mark, Tony's Light, Gillies Island, Gregory River, Leading Lights, Habitat Reserve, Paula's Beach, The wreck of the Apricot Venturer.

Exercise 2 Latitude and Longitude

1 (a) 23° 52' S, 151° 56' E
(b) 23° 55' S, 151° 58' E
(c) 23° 56' S, 152° 4' E
(d) 24° 9' S, 152° 0' E
(e) 24° 10' S, 151° 53' E

2 (a) Clubhouse
(b) North Reef Light
(c) Daves' Point Light
(d) Trents' Light
(e) Sue's Peak

3. North Reef Light and Dave's Light
4. Apricot Venturer Wreck and Sue's Peak

Exercise 3:- Nautical Mile P 38

(a) 3.5 Nm
(b) 6.5 Nm
(c) 3.3 Nm
(d) 6.0 Nm

Exercise 4:- Distance

(a) approx 12.5 Nm
(b) 8 Nm
(c) 12 Nm
(d) 14.5 Nm

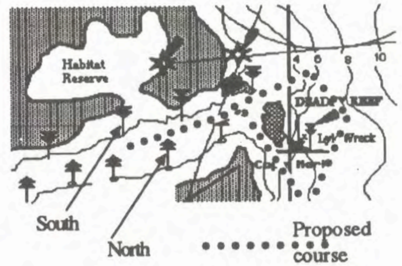
Exercise 5:- Distance, speed and time

Q1. (a) 90 Nm
(b) 24 Nm
(c) 35 Nm
Q2. (a) 5 Knots
(b) poorly
(c) 10knots
Q3 (a) 4 hrs
(b) 8 hrs

Exercise 6:- Bearings

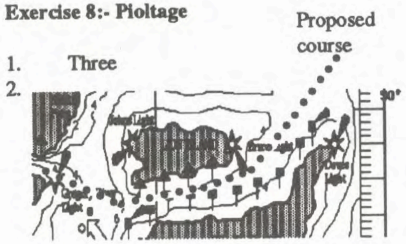
Q1. (a) 140°
(b) 55°
(c) 215°
(d) 240°
(e) 165°
Q2. (a) 10° +54' (1978)
Q3. 03°E
Q4. increase of 13°24'

Exercise 7:- Pilotage



Exercise 8:- Pioltage

1. Three
2.



3. You pass it on the port side so it is on your right because as you leave port, port markers are on our right.

Exercise 9:- Position fixing

Q1: Ans: 23°50.5'S, 152°06.5'E
Q2: Ans: 23°58'S, 151°55'E
Q3: Ans: 23°57'S, 151°58'E

NAVIGATION CERTIFICATE

This is to certify that the following level of achievement has been gained in this school's Navigation program.

....

CRITERIA

Sound Achievement

The student can

- Define latitude and longitude
- Identify major chart features
- Fix a position on a chart by triangulation
- Make simple calculations
- Use a pair of parallel rules accurately
- Take a bearing to fix a position on a chart
- Complete set tasks on time

High Achievement

The student can in addition to the above

- Convert magnetic bearings to true bearings
- Make calculations and graphs involving a tide book
- Predict weather forecasts from a weather map explaining common terms

Very High Achievement

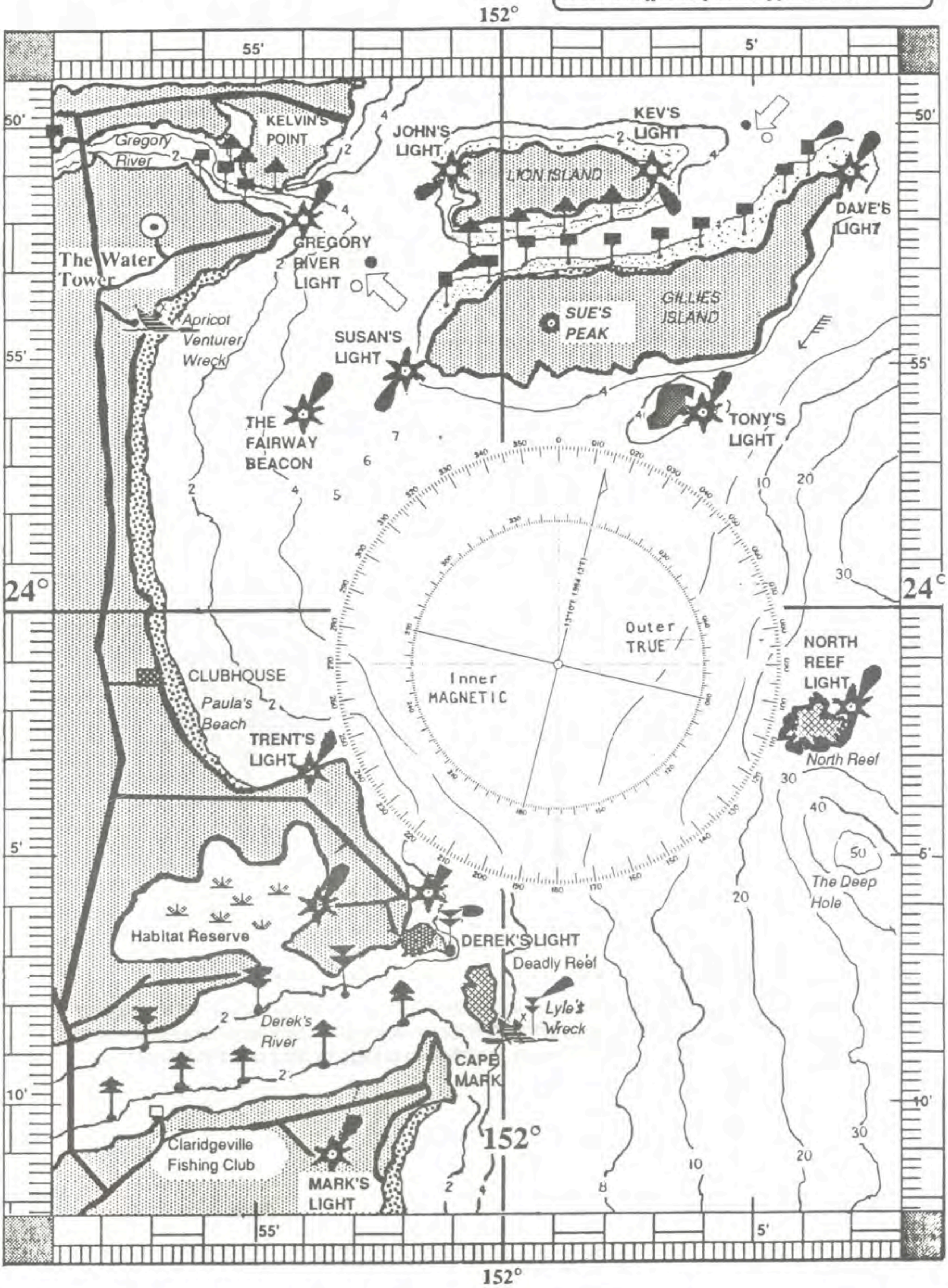
The student can in addition to the above

- Apply the rule of twelfths to calculate the depth of water at any point in the tide
- Perform complex problem solving exercises involving a number of course changes
- Write an extended answer to a set question in a logical and organised manner

Supervising Teacher: .... **Date:** ....

*H*YPOTHETICAL BAY

Caution:- *Values obtained may vary slightly due to photocopying of this page. Instructors should double check the answers to avoid confusion caused by rescaling due to lenses in different photocopy machines.*



CHAPTER 1

Charts

Q1. **What is a chart?**
Ans. A chart is a curved section of the earth's surface reproduced on a flat piece of paper.

Q2. **What is a map?**
Ans. A map is a representation of the earth's surface on a plain surface.

Q3. **Where will the major distortion be in the case of Mercator charts?**
Ans. In the case of Mercator charts the major distortion will be at the poles.

Q4. **Why can we use Mercator charts?**
Ans. Because only a small portion of the earth's surface is reproduced on most charts and only a small distortion will occur.

Q5. **What does a nautical chart show?**
Ans. A nautical chart used primarily for marine navigation shows Title and date of publication land out lines, prominent land features, (natural and man made), depth of water, channels, navigation markers and a compass rose.

Tides

Q1. **What is a tide?**
Ans. A tide is the periodic rise and fall of water on the earth's surface caused by the moon's rotation around the earth.

Q2. **How do tides vary? Ans.** Tides vary daily, weekly and monthly.

Q3. **When do spring tides occur?**
Spring tides occur every two weeks and are the highest tides in the month.

Q4. **When do Neap Tides occur?**
Neap tides also occur every two weeks and are the lowest tides of the month

Finding the tide height

Q1. **What is the method used to record the time of tides?**
Ans. The 24 Hour clock is used to record tides.

Q2. **How is the time between tides calculated?**
The Time between the tides is calculated by using the rule of twelfths.

Q3. **What does this rule state?**
This states that the tide will drop according to the following amounts

First hour	-	1/12 th of range
Second hour	-	2/12ths of range
Third hour	-	3/12ths of range
Fourth hour	-	3/12ths of range
Fifth hour	-	2/12ths of range
Sixth hour	-	1/12 th of range

Before you is a chart of the local area. Answer the following questions:

1. What is the deepest part on the chart?
2. What is the most Northerly point on the chart?
3. Why does a chart need latitude and longitude?
4. What date was the chart prepared?
5. Is there a scale on the chart and, if so, what scale is used?
6. What is the magnetic variation for the chart?
7. What are the main shipping lights nearest the local port?
8. What is the main degree of latitude and longitude?
9. Is the chart in fathoms or metres?
10. Is a lateral or cardinal system of buoyage used?

CHAPTER 2

Some Navigation instruments

Q1. **What is Navigation?**
Ans: Navigation is the art of directing a vessel at sea.

Q2. **How many degrees does the earth rotate in one hour?**
Ans. It rotates through 15 degrees each hour (24 x 15 = 360°).

Q3. **What significance is this?**
Ans: Each 15 degrees of east or west travel on earth represents one hour's difference.

Q4. **What is the lubber line?**
Ans: A 'lubber line' indicates the ship's head against which the helmsman steers the required course.

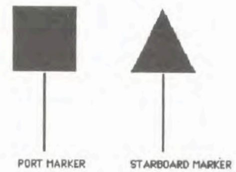
Q5. **Name three navigation instruments.**
Compass, sextant and chronometer

Buoys, Beacons and Marks

Q1. **On sighting a navigational mark, what must the mariner's reaction be?**
Ans: The mariner's reaction must be *instinctive, positive* and *correct.* Lack of this knowledge usually ends up in disaster.

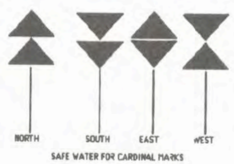
Q2. **Name the two systems that still operate in Australia.**
Ans: The old one is called the *Lateral System* and is characterised by two markers, *Port and Starboard.* The new one is *the Cardinal System* and uses four marks.

Q3. **Draw the two lateral marks and state the rule associated with each:**
Ans: Port markers are red squares, and are kept to the port side when entering port.



Q4. **Name some other lateral markers and state their uses.**
Ans: Special marks which indicate special features. Safe water marks which indicate there is navigable water all around sides and isolated danger marks which indicate isolated dangers of limited extent.

Q5. **What are the four main marks** in the cardinal system of buoyage?



CHAPTER 3:

CLASSROOM NAVIGATION

Q1. **Make a list of ten chart features that are not normally found on a map.**
Ans. Soundings, Cardinal marks, lateral marks, compass rose, latitude, longitude, direction of buoyages, habitat reserves, sea plane landing strips, submarine cables...

Q2. **What is the difference between latitude and longitude?**
Ans. On a chart, the **Latitude** scale is marked in degrees and minutes on either side, while the **Longitude** scale is similarly marked on the top and bottom of the chart.

Q3. **What does 1 degree and one minute on a chart represent?**
Ans. 1 degree = 60 minutes (1° = 60') 1 minute = 60 seconds (1' = 60")

Q4. **What is the starting place of all longitude measurements?**
Ans. **The Greenwich Meridian** is the traditional starting place of all longitudinal measurements

Q5. **What is the starting place for latitude?**
Ans. Latitude is the measurement scale which begins at the Equator (0°)

Q6. **How should latitude and longitude be written?**
Ans. The position of the object is stated by first giving the line of latitude of its situation (in degrees, minutes and seconds) and then giving the line of longitude (in degrees, minutes and seconds).

THE NAUTICAL MILE

Q1. **What is a nautical mile?** Ans: One minute of LATITUDE.

Q2. **How is distance measured on a chart?**
Ans. Distance is measured by dividers. The spread of the divider's points are used to carry the measurement of the latitude scale, where it can be read off in minutes.

Q3. **Where should measurement be taken on a chart and why?**
Ans. Because of variations due to the chart's distortation, distance readings should be taken from the LATITUDE scale at a point roughly level with the boat's position.

DISTANCE AND SPEED

Q1. **What is the first thing to do when working out distance?**
Ans: When you go to work out distance, you will have to draw arcs of safe distance

Q2. **What is the formula for speed?**
Ans:

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

Q3. **What measures the speed on a vessel?**
Ans. The speed of a vessel is measured by a speed log. This computes the time it takes to travel a nautical mile.

Q4. **How is speed measured? Ans** Speed is measured in knots.

Q5. **How did this term originate?**
Ans The term originated from the practice where a piece of wood, **the log**, was thrown overboard and allowed to flow out behind the boat. This line was marked in knots. One seaman would use an hour glass filled with sand to time the number of knots that flowed through the other seaman's hand in a certain time. This indicated the speed of the ship.

Q6. **What is a knot equal to? Ans.** 1 knot is equal to 1 nautical mile per hour.

BEARINGS

Q1. **How are bearings taken on a chart?**
Ans. From the inside of the compass rose out to the sides

Q2. **Name the two types of bearings.**
Ans. True and Magnetic

Q3. **What is the standard form of giving a bearing?**
Ans All bearings are usually given as true

CHAPTER 5

Q1. **Name six pieces of navigation equipment that can be found on a boat.**
Ans: The sextant, The Radio Direction Finder, The Depth Sounder, Radar, Decca and Loran ,Gyro Compass

Q2. **What two functions does the RDF have?**
Ans. It is used to provide time checks for the navigator's clocks or watches, and it can be adapted for picking up directional signals which provide bearings for use in plotting the boat's position.

Q3. **What does the term RDF stand for and how is it constructed?**
Ans. RDF stands for Radio Direction Finding and the adaptation of a normal radio receiver for this purpose involves the fitting of a 'loop' aerial and compass card or pelorus.

Q4 . **What does a modern depth sounder consist of and how does it work?**
Ans. The modern depth sounder is an electronic version of the same thing which uses the sonic principle of bouncing a 'pulse' off the bottom. A transducer fitted to the bottom of the boat transmits an electronic pulse which bounces off the sea bed and is picked up by a small receiver, also in the bottom of the boat. By measuring the time from transmission to receiving, the sounder records the depth of water under the keel.

Q5. **How is this measurement indicated?**
Ans. The measurement may be indicated in a number of ways - a neon blip on a dial is one commonly in use and a continuous trace on a moving paper another.

Q6. **What is the advantage of the latter?**
Ans. The latter has the advantage that it traces a record over a period

Q7. **What is radar and how does it work?**
Ans. Radar works on a somewhat similar principle to the depth sounder. An electronic pulse is transmitted from the scanner. It 'bounces' back off shore or other objects in the vicinity and the 'echo' is picked up by the receiver. As the scanner rotates through 360 degrees, these echoes are converted into a map-like picture on a cathode tube with the boat as the centre of the picture and the local scene laid out around the full 360 degrees horizon. The set incorporates means of measuring bearings and distances and thus the navigator can carry out his position plotting without leaving the comfort of the cabin.

Q8. **Why must radar be used with a certain degree of caution?**
Ans One of its biggest drawbacks is the tendency of the pulse to 'echo' only off certain objects. A cliffy coastline, for example, will usually present an excellent picture on the radar screen

Q9. **How are modern charts attempting to accommodate this?**
Ans. Naval charts are now being printed with 'radar prominent' areas marked clearly on the coastlines. These are the areas which throw up a good echo on the radar screen, and can be readily identified by the navigator, thus reducing the confusion which might otherwise occur when parts of the coastline are visible on the screen, yet other areas do not show up. Similarly, navigation marks such as buoys or channel indicators which do not show up too well on the screen, are fitted with radar reflectors, a device which increases the strength of the radar echo and creates a much stronger 'blip' on the screen.

Q10. **What are the two main causes of error in the compass**
Ans. There are two main sources of error in a boat's compass - the result of some physical damage, or an error induced by outside magnetic forces.

Q11. **What is error in variation and how is it caused?**
Ans. This is the error caused by the earth's magnetic and true poles being in different places. It manifests itself in every compass by deflecting the needle away from the *true* north until it is pointing at *magnetic* north.

Q12. **What is the error of deviation and how does it vary?**
Ans. This is the deflection of the needle by the magnetic influence of some object on board the boat.

Q13 . **Give an example of this deviation and how does it vary**
Ans. The best example is that of placing another magnet, or even a piece of metal, near the compass. It varies greatly according to the boat itself, the material from which it is constructed and any magnetic material carried aboard.

Q14. **How does it vary with fibreglass boats?**
Ans. In the case of fiberglass, and timber craft, there is little in the hull structure to cause problems.

These tables have been reproduced courtesy of the Queensland Department Harbours Marine specifically for Activities 1.2 and 1.3 and are to be used for Educational purposes only.

CAIRNS

MAY

	Time	m		Time	m
1	0221	0.99	16	0311	1.02
	0815	2.32		0850	2.12
SU	1424	0.51	MO	1508	0.36
	2101	2.55	●	2201	2.75
2	0252	1.06	17	0355	1.15
	0836	2.22		0923	1.91
MO	1452	0.49	TU	1544	0.49
○	2133	2.58		2243	2.64
3	0328	1.16	18	0446	1.29
	0900	2.08		1001	1.70
TU	1523	0.52	WE	1623	0.67
	2208	2.56		2335	2.47
4	0409	1.28	19	0559	1.41
	0930	1.92		0650	1.42
WE	1559	0.60	TH	0804	1.40
	2252	2.48		1040	1.49
				1704	0.86
5	0502	1.41	20	0044	2.30
	1008	1.73		0945	1.31
TH	1642	0.72	FR	1145	1.32
	2352	2.37		1752	1.04
6	0837	1.48	21	0224	2.20
	1059	1.54		1126	1.19
FR	1735	0.87	SA	1602	1.29
				1910	1.18
7	0145	2.30	22	0340	2.17
	0949	1.31		1154	1.10
SA	1338	1.41	SU	1654	1.41
	1917	0.99		2117	1.22
8	0322	2.40	23	0427	2.17
	1024	1.12		1200	1.04
SU	1535	1.57	MO	1726	1.55
	2107	0.95		2223	1.20
9	0415	2.52	24	0505	2.18
	1056	0.91		1150	0.96
MO	1635	1.79	TU	1757	1.70
☾	2219	0.86	☽	2313	1.17
10	0505	2.62	25	0538	2.18
	1133	0.70		1204	0.86
TU	1731	2.03	WE	1828	1.86
	2320	0.78		2355	1.16
11	0552	2.68	26	0608	2.17
	1211	0.50		1224	0.76
WE	1826	2.28	TH	1857	2.02
12	0013	0.73	27	0032	1.15
	0637	2.67		0632	2.16
TH	1250	0.35	FR	1245	0.66
	1918	2.50		1924	2.18
13	0102	0.74	28	0104	1.14
	0717	2.60		0654	2.14
FR	1327	0.27	SA	1307	0.55
	2004	2.67		1951	2.36
14	0147	0.80	29	0135	1.12
	0751	2.47		0721	2.12
SA	1401	0.24	SU	1331	0.45
	2045	2.77		2021	2.52
15	0229	0.90	30	0208	1.09
	0820	2.30		0750	2.09
SU	1434	0.27	MO	1401	0.36
	2123	2.80		2055	2.64
			31	0247	1.09
				0822	2.02
			TU	1435	0.32
			○	2133	2.70

HARBOURS MARINE

Caring for our coast

Symbols for Moon Phases

● new moon ☽ 1st quarter ○ full moon ☾ 3rd quarter

MACKAY OUTER HARBOUR

MAY

	Time	m		Time	m
1	0438	1.15	16	0451	0.98
	1025	4.89		1035	4.82
SU	1641	0.75	MO	1647	0.42
	2253	5.44	●	2308	5.94
2	0515	1.28	17	0536	1.04
	1059	4.62		1121	4.60
MO	1712	0.91	TU	1726	0.58
○	2327	5.39		2353	5.86
3	0554	1.46	18	0623	1.16
	1135	4.30		1209	4.36
TU	1744	1.13	WE	1808	0.84
4	0002	5.26	19	0040	5.66
	0636	1.69		0712	1.32
WE	1211	3.97	TH	1302	4.13
	1815	1.40		1851	1.16
5	0038	5.08	20	0129	5.39
	0721	1.91		0807	1.49
TH	1253	3.67	FR	1358	3.94
	1849	1.66		1942	1.50
6	0122	4.87	21	0223	5.09
	0818	2.10		0907	1.62
FR	1346	3.43	SA	1502	3.80
	1935	1.92		2048	1.80
7	0219	4.68	22	0323	4.81
	0933	2.16		1015	1.66
SA	1504	3.32	SU	1621	3.78
	2045	2.11		2208	1.98
8	0333	4.58	23	0437	4.65
	1056	2.03		1127	1.56
SU	1639	3.42	MO	1745	3.94
	2213	2.13		2332	1.96
9	0456	4.63	24	0551	4.64
	1209	1.72		1230	1.35
MO	1806	3.76	TU	1849	4.24
☾	2340	1.95	☽		
10	0609	4.83	25	0045	1.78
	1302	1.36		0650	4.72
TU	1904	4.21	WE	1318	1.13
				1936	4.55
11	0055	1.65	26	0138	1.59
	0705	5.03		0735	4.77
WE	1345	1.02	TH	1356	0.96
	1949	4.66		2013	4.82
12	0152	1.36	27	0223	1.45
	0750	5.15		0813	4.75
TH	1423	0.76	FR	1431	0.85
	2028	5.06		2047	5.04
13	0239	1.16	28	0302	1.37
	0831	5.18		0848	4.67
FR	1458	0.56	SA	1504	0.81
	2107	5.41		2120	5.22
14	0323	1.03	29	0340	1.34
	0910	5.13		0923	4.55
SA	1533	0.43	SU	1537	0.80
	2145	5.69		2154	5.37
15	0407	0.98	30	0420	1.32
	0952	5.01		1000	4.43
SU	1608	0.37	MO	1610	0.82
	2225	5.88		2230	5.49
			31	0501	1.32
				1040	4.30
			TU	1647	0.87
			○	2308	5.55

CHAPTER 6

Q1. How do clouds form?

Ans. Clouds form when the water vapour in the air condenses into small droplets, so small that they float around in the air currents. If large enough numbers of these droplets come together in one area, they may become visible to us as clouds.

Q2. What is the dew point?

Ans. The dew point is the temperature at which the droplets become visible.

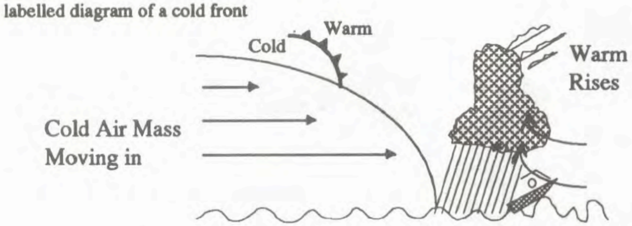
Q3. Name four important cloud types

Ans. Stratus, Cirrostratus, Cirrus, Nimbostratus, Cumulonimbus

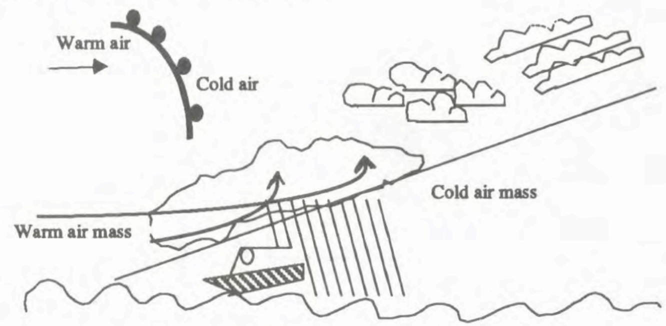
Q4. What is a front?

Ans. A front is the boundary between a cold air mass and a hot air mass and is usually associated with gusty winds and rain.

Q5. Draw a labelled diagram of a cold front



Q6. Draw a labelled diagram of a warm front



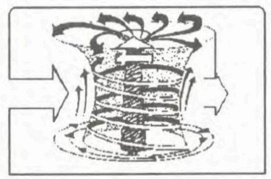
Q7. What are 5 signs associated with cyclones

Ans

1. Barometer falling fast, to an exceptionally low reading.
2. A marked heavy ground swell. This is quite different from normal swell conditions.
3. A distinctly lurid appearance about the sky in the direction of the storm.
4. As the storm approaches, a marked shift in the direction of the winds can be seen as well as increasing wind force.
5. A distinctly howling wind - these winds are quite distinctive.

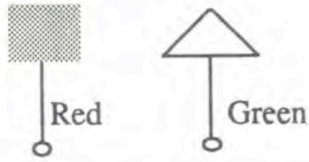
Q8. What is the difference between a high pressure and a low pressure system and draw a sketch of a cyclone

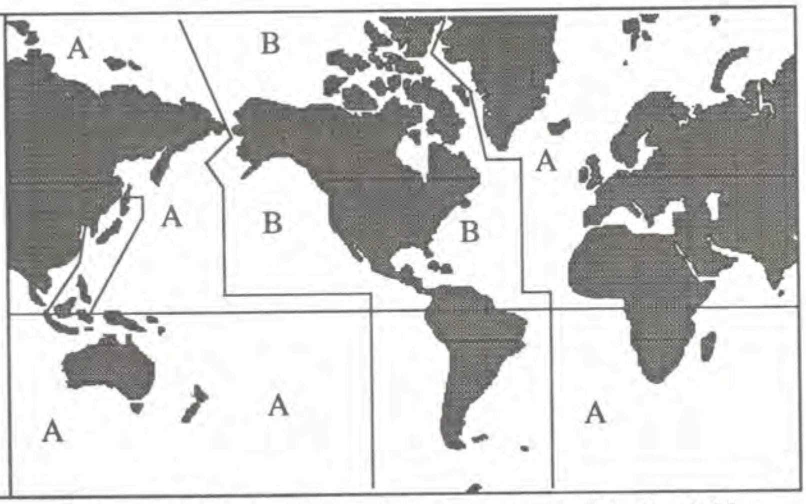
Ans. Highs are anticyclones where the winds blow anticlockwise



In system A, Red is passed to the left when entering port and Green on the right.

In system B, Green is passed on the left and Red on the right when entering a port.





IALA means the International Association of Lighthouse Authorities. Agreed to in 1980.

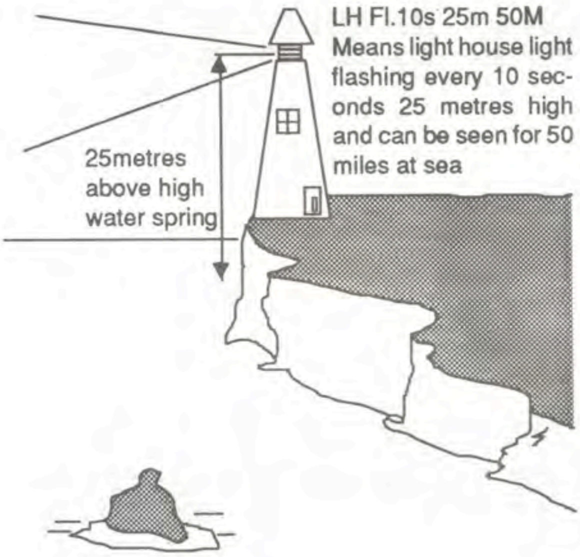
E.P.I.R.B. Stands for an Emergency Position Indicating Radio Beacon and is a small buoyant transmitter which is used in a distress situation that can be tracked by searching aircraft or ships.

UNITS OF MEASUREMENT

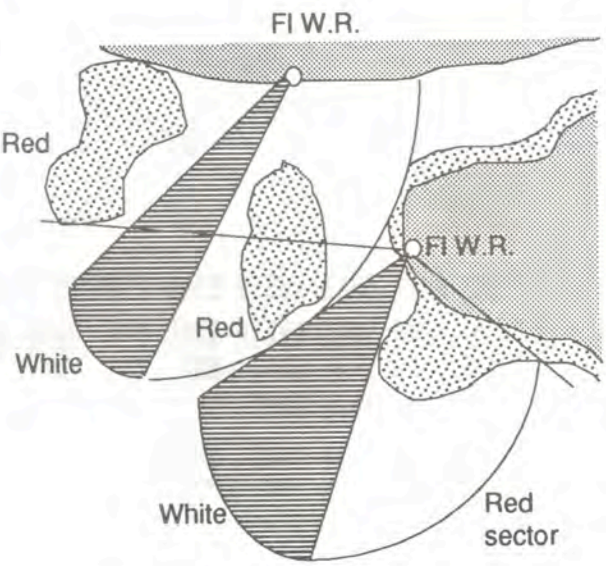
DISTANCE	DEPTH
1 nautical mile = 1.825 kilometres 1 kilometer = 0.54 nautical mile	1 fathom = 1.829 metres = 6 feet 1 metre = 0.547 fathoms

LIGHTS AND LIGHTHOUSES

On charts these are marked as a variety of symbols and forms. Two are shown below. Light houses let the navigator know how far from land and sectored lights help stay in channels at night.



Sectored lights show sectors of safe passage. White safe and red danger. A vessel can therefore enter a port at night by staying in the white sectors as shown below.



MAGNETISM, MAGNETIC VARIATION AND DEVIATION

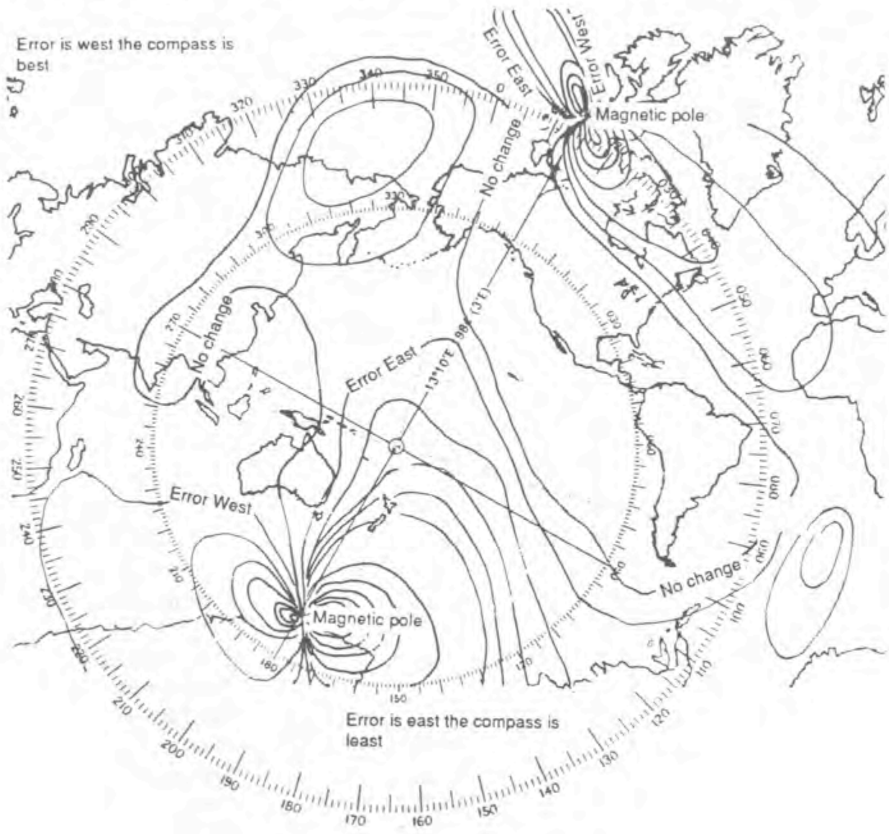
Deprived of all visual indications, the navigator loses all sense of direction. There is an old saying that the compass is the heart and the anchor the hand. All navigators need to understand how a compass guides the ship but it is full of errors caused by the earth's magnetism and the steel in the ship. The map below shows the earth's magnetic field and explains why charts are corrected for east or west variations.

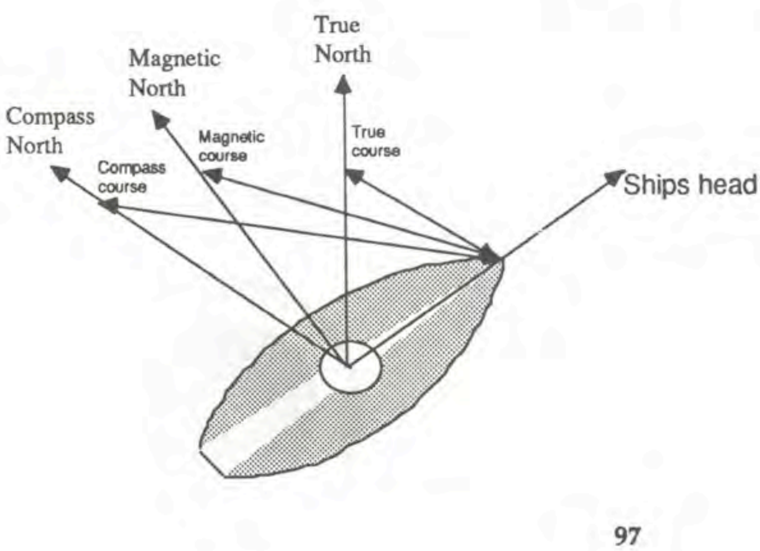
Definitions: *Variation is the angle between True and Magnetic North caused by the magnetic north pole moving. Deviation is the deflection of the compass needle from true north caused by magnetic influences in the boat.*

Corrections for: *Corrections for deviation involve swinging the compass which is not discussed in these notes. Corrections for variation east or west are made according to where you are on the earth's surface. The map below shows magnetic north and a bearing taken from a South Pacific Island with a variation in 1984 of 13°10'E. The E stands for east and the correction is made as follows.*

Course laid on chart	*275°(T)*
Compass error	*13°(E)*
Course to steer	*262°(C)*

If the error is east the compass is least. i.e. you subtract from chart bearings to find out which course to steer.





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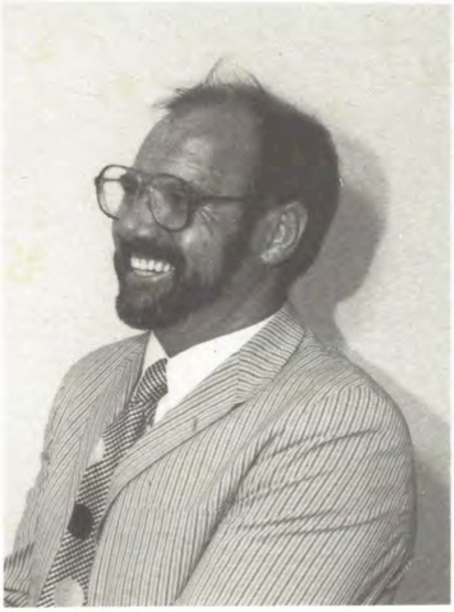

ABOUT THE AUTHOR

Bob Moffatt is a Science graduate of the Queensland University majoring in Marine Zoology and has completed a Graduate Diploma in School Administration from the Brisbane College of Advanced Education specialising in Marine Management Systems.

He began teaching marine studies programmes 15 years ago in the Wide Bay Region where he developed a programme for Senior Zoology students. In 1976 he received a grant from the Commonwealth Schools Commission to begin the Gladstone Oceanographic Studies Program in Queensland's Central Region. In 1983 he founded the Brisbane South Region Marine Studies Program on Queensland's Gold Coast from which many curriculum materials have been developed.

Bob has been a pioneer in the design and implementation of curriculum materials. He built a prototype Marine Studies building in 1985 and actively promoted marine education throughout Australia largely from the sales of his earlier books. He has had much to do with the purchase of marine resources in Queensland schools and is presently assisting with the Marine Studies Board of Secondary School Studies Syllabus. He was a foundation member of the Marine Studies Education Society of Australasia.

In 1986 he undertook, at his own expense, a world tour to 14 overseas countries to gather ideas to further marine studies school based curriculum development in Queensland schools. In addition, he represented the Queensland Education Department at the Pacific Area Conference of Marine Technology in Hawaii on an honorary basis.

Bob was a recipient of the Science Teachers Association Teacher of the Year Award in 1985. He won the Inaugural Australian Castrol Sea Safety Award for excellence in the design of a marine safety programme in 1987 and was nominated for the Shell Achiever's Award in the same year. Bob enjoys surfing as often as possible with his three sons. He has worked with private enterprise as a consultant in his own time and has written many curriculum projects for the Great Barrier Reef Marine Park Authority on an honorary basis.

In 1988 and 89 he was invited as Australian representative to a seminar in marine studies education in Fiji. This meeting commissioned modification of this book for a training course for South Pacific Teachers sponsored by UNESCO in 1989.

He is at present a free lance marine education specialist working on the Gold Coast designing marine education interpretative materials for government and private organisations.

THE HISTORY BEHIND THE BOOK

In 1978, Bob studied with Allistair Martin, director of the Woodbridge Marine Studies Centre in Tasmania. It was there that the idea for this book was conceived. The first drafts were published on an honorary basis by the Science Teachers Association of Queensland and later by the Brisbane South Marine Studies Project . This new book seeks to provide the content and disciplined writing lacking in the early publications. It is hoped that students will have a greater understanding of the complexities involved in navigation and understand some of the rules associated with its practical application.

WET PAPER PUBLICATIONS

Snorkelling

Fisheries Biology

Classroom Navigation

The Barrier Reef World

Introduction to Boating

Introduction to Camping

A Study of Seawater

Coastal Studies

Oceanography

Teachers Guides

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