Course Outline for Able Requirement 10: Piloting and Navigation

By Douglas D. Love, Mate, SSS Chaser, Napa, California
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Dedication and Acknowledgements

The author would like to dedicate this work to the following person:

Commodore Russ Blanchard

Former Commodore of Silverado Area Council, BSA, recipient of the Baden Powell Award and the Silver Beaver. Past Commodore of the Benicia Yacht Club, former Vice-Mayor of the City of Benicia, dear friend and mentor. It was Commodore Blanchard who introduced me at the age of fourteen to Sea Scouting and took me under his wing. His encouragement and dedication to Scouting helped make me the man I am today. Commodore Blanchard sailed on to calmer seas and safer waters several years ago but his memory stays with me as does his influence. May you always have fair winds and following seas, Commodore.

And gratefully acknowledge the following people for their help and input:

Joshua Gilliland, Western Regional Commodore, Sea Scouts, Boy Scouts of America who started me on this project. It has been a pleasure.

Glenn Draper, Assistant District Commissioner for Sea Scouts, Long Beach Council for his input and encouragement.

Charles Riedmuller, USCG (ret), USCG Unlimited Master, former navigation instructor at California Maritime Academy, fellow Mate aboard the SSS Chaser, mentor, shipmate and friend for his support, input and editing skills and finally,

Hope Gorman, Quartermaster Sea Scout and California Maritime Academy student for her proof reading and input.

This work is my own and is to be used solely as a guide for the teaching of Able Requirement #10: Piloting and Navigation. It is the result of over twenty years of teaching basic piloting and navigation and twenty five years of experience as a public school teacher. It is by no means comprehensive and may be modified to fit the needs of the individual ship. I hope that this modest effort is of some use.

This course outline is NOT an official publication of the Boy Scouts of America and should only be used as a general reference and outline.

In Service to Scouting,

Douglas D. Love
Benicia, California
April 2014

Able Requirement 10: Piloting and Navigation

Purpose: To acquaint the Scout with the basic techniques and methods of inland and near-coastal piloting.

Materials: Record book suitable for keeping a log. To meet legal requirements, the log book must be bound, not spiral bound or a three ring binder, and must have the pages sequentially numbered.
Dividers
Navigator's triangles, parallel rules or a course plotter.
Hand bearing compass, Pelorus, or some other method of taking bearings. (i.e. Radar or bearing ring for the ship's compass.
Global Positioning System Receiver
Local navigational charts
Scratch Paper
Calculator
0.5mm #2 Mechanical Pencils
Ball point pens
White plastic erasers
Drawing Compass
GPS Receiver (Either hand held or mounted on vessel)
Sea Scout Manual
Chapman: Piloting & Seamanship (for reference.)
Dutton's Nautical Navigation (for reference.)
Pub. No. 9: The American Practical Navigator: Bowditch (for reference.)
OPNAVINST 3100.7C (See text and references)
Pub. No. 1310 Radar and Maneuvering Board Manual (for reference)

Section a. Ship's Log: For this section, the Scout must be able to describe the deck log kept aboard the ship's principal craft and keep a complete log for a minimum of three cruises. The Scout must keep an accurate log while they are on navigation watch if the cruise is longer than four hours duration. Three complete watches will satisfy the requirements of this section.

Materials: Blue or pens
Bound journal with the pages sequentially numbered.

Procedure: The instructor should have a working knowledge of how to keep a proper deck log. If the instructor is unfamiliar with what is to be contained in a deck log, he or she can refer to OPNAVINST 3100.7C which can be found here. OPNAVINST 3100.7C is the standard United States Navy instructions for keeping a deck log and it is followed, with some modification throughout the merchant services of the United States. The main point is that a deck log should contain the following information:

Major changes to a vessel status including:
a. Preparing to get underway
b. A list of the personnel on board the vessel (If a separate manifest is not kept.)

c. The time that major ship's equipment is brought online and shut down i.e. generators and main engines.
d. The taking on of fuel and other bunkers.
e. The time and duration of safety drills.
f. Any significant occurrences during the voyage.
g. The time that the vessel got underway and arrival at anchorage or destination.
h. The time of ceremonies and their nature. (If any.)
j. Major navigational data including course changes (including course adjustments to avoid collision), major speed changes, landmarks, fixes,
DR positions, weather observations, sea state, course and speed observations.
k. The time of arrival and leaving of ship's personnel.

Because the deck log is the legal record of a ship's voyage, it cannot be stressed that a complete and accurate log must be kept. There may be other logs such as a radio log, liberty log, night watch log and engineering log that may supplement the deck log but the deck log is the primary source for information about a vessel's voyage. It is not simply a list of courses and fixes although that may be the majority of entries. Below is an example:

	SSS Enterprise: Cruise from Pier 1 Majel Bay to Anchorage 4 Barrett's Cove *01 April 2014*
1200	*Making preparations to get underway. Weather Clear. Wind 0-5 kts NW, Calm.*
1215	*Main Engines fired and STBD SSG brought online. Shore power disconnected.*
1220	*Underway for Anchorage 4, Barrett's Cove CRS 135T SPD 5.0*
1240	*Passed Majel Bay Marker #4 to STB. CRS 135T SPD 5.0*
1300	*GPS Fix 40° 15.4' N 112° 13.7' W Course change to 180T SPD 7.0*
1306	*Altered course to 170T to avoid multiple vessels*
1310	*Returned to 180T SPD 7.0*
1315	*Passed Majel Bay Marker #2 to STB. CRS 180T SPD 7.0*
1320	*Arrived at Barrett's Cove Anchorage 4. POSIT 40° 13.4' N 112° 13.3'WAnchored in 18 feet of water, 2 shots of chain on STBD anchor. Sandy bottom. Main engines secured.*
1330	*All hands report for lunch.*
1400	*Lunch Secured. Launched small boat for MOB Drill*
1405	*Small Boat recovered. Secured from MOB Drill*
1430	*Small boat launched for liberty. Anchor watch set.*
	Log Secured,
	Pavel Chekov.
	Navigator, SSS Enterprise

Please note that the above is merely an example and is by no means complete. When making log entries, the entries must be in pen and legible. If there is a mistake in the entry, it is to be struck through with a single line, ~~like this~~ and initialed. When the log is secured, it is to be signed by the navigator of the watch or by the person who secures the log. The log is to be kept onboard the vessel until such time as it is full. At that time it is to be replaced with a new log book and the completed log book may be stored elsewhere as long as it remains in possession of the ship.

Section b. Plotting a course. For this section, the Scout must plot a course of at least three legs and successfully execute the course using dead reckoning. The Scout will have successfully completed this requirement once a cruise is taken and successfully completed following the Scout's course

Materials: Local Navigational Chart
0.5mm Mechanical pencils
Ball point pens
Dividers
Triangles/Course plotter/Parallel Rules
White Eraser
Paper
Calculator or Navigational Slide Rule to aid in calculations (optional)
Stopwatch or accurate time keeping device
Deviation table for their Ship's primary vessel.

Procedure: The instructor MUST have a working knowledge of how to lay and follow a course using dead reckoning procedures. If the instructor is not familiar with the procedures, he or she should familiarize themselves with the contents of pages 181-184 of the Sea Scout Manual, Chapters 16 and 18 of Chapman, Chapter 9 of Dutton's or Chapter 7 of Bowditch. For this requirement the Scout is to lay out a course and execute it. The Scout must lay out a course using the procedures and notation learned in in Ordinary Requirement #10(f) and then the course must be followed successfully on a cruise. Ideally, the course must be accurate to within one degree and $1/10^{th}$ of a nautical mile. The estimated time enroute (ETA-ETD) should be within plus or minus 5 minutes of that which is planned excluding time for unforeseen circumstances. The following table may be used to create a dead reckoning table for use on the cruise:

Time	LAT	LONG	True	Var.	Mag.	Dev.	Comp.	Spd.	Dist.	ETA

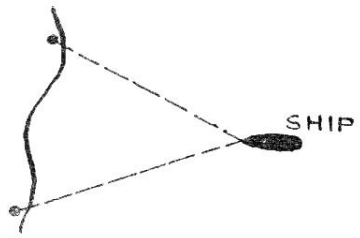
In addition, the Scout should keep an accurate deck log of the cruise and suggest when and where the course changes are to be made to complete the course.

Section c. **Position Determination:** For this section the Scout must be able to fix or estimate their vessel's position by each of the following methods: by bearings from two known objects, by a running fix and by establishing an estimated position (not a fix).

Materials: Local or Training Navigational Chart
Dividers
Triangles/Course Plotter/Parallel Rules
Hand Held Bearing Compass or Pelorus
Paper
0.5mm mechanical pencils
White Eraser
Pens

Procedure: The instructor should have a working knowledge of how to fix a position by a bearing from two known objects, take and plot a running fix and establish an estimated position. If he or she does not, the instructor must familiarize him or herself with pages 186- 187 of the Sea Scout Manual, Chapter 18 of Chapman, Chapter 12 of Dutton's, or Chapter 8 of Bowditch.

Bearing from two known objects. Basically, if the bearing to two known or more objects can be taken and plotted, where the bearing lines cross or intersect, (also known as lines of position or LOPs) is the position of the observer. See illustration below:

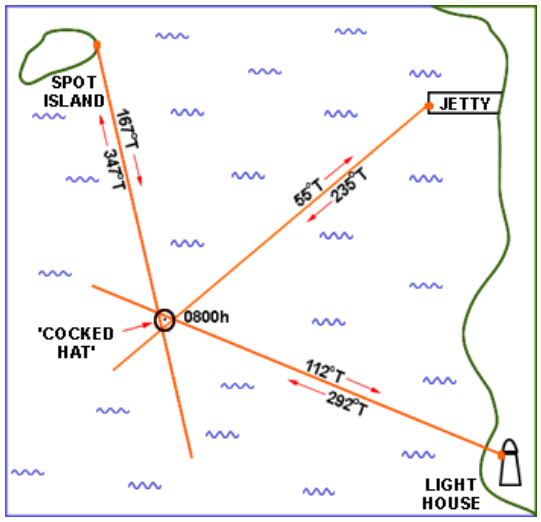


http://www.gutenberg.org/files/27642/27642-h/images/fig010.jpg

In practice, a known object is observed either with a pelorus, which gives a *relative* bearing to the observer or with a hand held bearing compass, which gives a bearing relative to magnetic North. Either method is accurate and will determine a fix. With a pelorus, the navigator takes a sight on the first object and says "Mark, Mark, Mark". The helmsman then gives the navigator the course at that time. The navigator notes the time and the course and the bearing of the object. The navigator then repeats the procedure for the second known object. In order to get the **True** bearing of the object, the navigator must add the observed and course bearings (subtracting 360 if the result is more than 360) and that will be the **TRUE** Bearing of the object which can then be plotted on the chart if steering by true courses. If steering by magnetic compass, the bearings must then be corrected for variation and deviation. Once the navigator has plotted the LOPs of the objects, the intersections of the LOPs are the vessel's position on the chart and constitute a fix at the time previously noted. The LOPs are to be labelled with the time and the fix is to be circled and labelled with the time.

For bearings taken with a handheld bearing compass, the bearing to the objects and the time of observation are to be noted and then the magnetic bearing must be corrected to true. This is done by adding easterly or subtracting westerly variation as needed. Since deviation is unknown, it is ignored. The resulting **TRUE** Bearings are plotted and labelled on the chart and the fix is then circled and labelled.

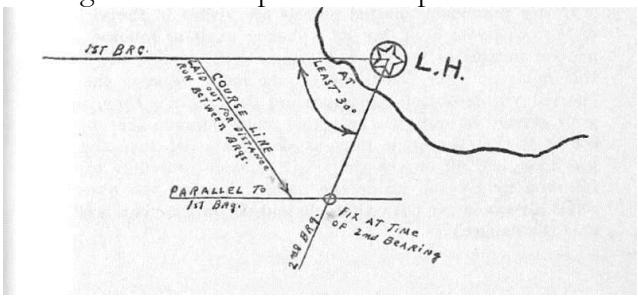
When using three or more objects, quite often the LOPs will not intersect, but instead will form a small triangle known as a "Cocked Hat". This is caused by the vessel moving as the observations are taken or errors in the reading of the bearings:



http://www.ukdivers.net/images/cn3.gif

In that case the fix is in the center of the triangle and labelled appropriately. Visual bearings can be taken from buoys **BUT** since a buoy is not fixed but swings about its mooring and its exact position is unknown, the position obtained is an estimated position and is to be treated as such.

Running Fixes: Sometimes it is not possible to observe two known objects at the same time. In that case, a *running fix* is used to determine the vessel's position. To establish a running fix a bearing to a known object is taken and plotted. After a time has elapsed, that LOP is advanced along the course line the amount the vessel has assumed to travel (known as advancing the LOP) and a second bearing is taken and plotted. The position of the vessel is where the two LOPs intersect.

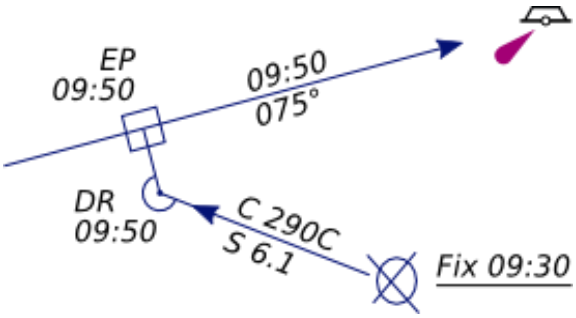


http://www.ibiblio.org/hyperwar/USN/ref/PT-Manual/img/MTBM-3-6-6.jpg

This is because the observer can only be at that spot if the two observed LOPs are accurate. The fix obtained is then circled and labelled RFix with the time of the second observation. Running fixes

are less accurate than fixes by two or more objects because the direction and speed travelled are averages and not actual directions and speeds. The same technique can be used for taking bearings from two different objects at two different times. The more the first LOP is advanced, however, the less accurate the Running Fix. Again, this is due to variations in the actual course steered and the actual speed made good. Furthermore, the bearings **MUST** be at least 30° apart for the running fix to be accurate.

Estimated Position: An estimated position (EP) is a dead reckoning position corrected by other known factors such as current direction (set), current velocity (drift), wind direction and velocity, depth of water or a bearing on one object. To determine an Estimated Position, the navigator must take a bearing on a known object and plot the LOP. The navigator then plots the DR position for the same time as the LOP. The navigator then draws a line perpendicular to LOP from the DR position and intersects the LOP. This gives the navigator the most probable estimate of the ship's position at the time of the observed bearing.



http://www.sailingissues.com/vier/estimated-position.png

An Estimated Position is **NOT** a fix. Instead it is the "best estimate" of the ship's position based on the information available to the navigator at that time. It can be used as an assumed position until further information becomes available to establish a fix.

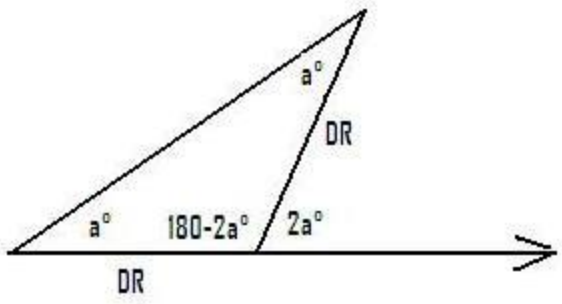
NOTE: A Scout has successfully completed this section when he or she has either fixed the vessel's position by plotting two or more bearings and plotted a running fix and plotted an estimated position either while underway or when given a set of problems by the instructor.

Section d. Doubling the angle on the bow and Danger Angles. For this section a Scout must be able to "double the angle on the bow" to determine the range to a known object and be able to set danger angles to avoid navigational hazards.

Materials: Local or Training Navigational Chart
Triangles/Course Plotter/Parallel Rules
0.5mm Mechanical Pencils
Pens
Paper
White Eraser.

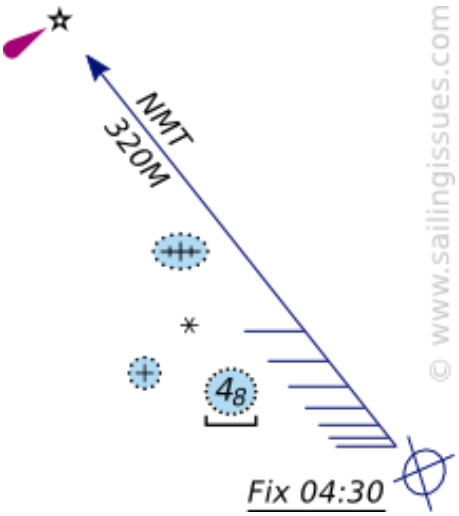
Procedure: The instructor must be familiar with doubling the angle on the bow and the setting of danger angles. If not the instructor must familiarize him or herself with pages 187-188 of the Sea Scout Manual, Chapter 18 of Chapman, Chapter 12 of Dutton's or Chapter 8 of Bowditch.

Doubling the Angle on the Bow: Doubling the angle on the bow is a technique used to determine the range to an object. It is useful when trying to avoid a headland or to try to establish an estimated position. It makes use of the properties of an isosceles triangle in that the adjacent and opposite sides are equal. That means that of you sight an object at 30° off your bow plot that LOP, when you sight the same object at 60° off your bow and plot that LOP; the distance run between the two plots will equal the distance you are from the object at the time of the second bearing. Since you have the range and bearing to the object, this is considered a special type of running fix.



http://deckskills.tripod.com/cadetsite/id100.html
Any pair of angles can be used for this purpose by using Table 18 in Bowditch and following the directions contained in Article 821 on page 124.

Danger Angles: Danger angles are used when navigational hazards are to be avoided. The navigator will measure the angle to a charted hazard and then compute the course to the hazard. The navigator will then plot a course line to the hazard and label it either NMT for not more than and NLT for not less than with the compass course not to be steered and then hatch the danger angle on the side if the hazard to be avoided. This is especially useful in unfamiliar waters, at night or when there are shoals or other hard to detect charted hazards.



http://www.sailingissues.com/vier/danger-bearing.png

Section e. GPS Navigation: For this section, the Scout must be able to discuss how the Global Positioning System works and understand the use of waypoints in navigating by GPS. The Scout must also be able to navigate a course underway using GPS and a minimum of three waypoints.

Materials: GPS Receiver
Navigational Chart
Dividers
Triangles/Course Plotter/Parallel Rules
0.5mm Mechanical Pencils
Pens
Log Book
White Eraser

Procedure: The instructor must be familiar with the operating principles and use of GPS in marine navigation. If not, the instructor must familiarize him or herself with page 189 of the Sea Scout Manual, pages 727-732 of Chapman, Chapter 17 of Dutton's or Chapter 11 of Bowditch. The instructor should also be familiar with the GPS receiver that is to be used for the fulfillment of this section of the requirement. **PLEASE NOTE: The use of built in GPS capability in many Smartphones or Tablets will NOT fulfill this section of the requirement.**

The Scout should know that the GPS apparatus consists of two parts; the satellite constellation and the receiver. He or she should know that there are 24 GPS satellites in geosynchronous orbit around the Earth. Twenty one of them are actively used for navigation and three are reserved in case of a failure of one of the others. The Scout should be able to tell the instructor that the GPS receiver computes its position on the Earth based upon radio signals received from three or more (usually more) satellites and that currently the civilian GPS system with Wide Area Augmentation Service is accurate to five meters (16.4 feet) or less. The Scout should be able to tell the instructor that there can be GPS error caused by atmospheric conditions, solar flares and other weather related causes but in general the GPS system maintains its accuracy at least 95% of the time. The Scout should be able to explain that waypoints are geographic locations expressed in latitude and longitude which are programmed into the GPS to create a route. The route is then followed from waypoint to waypoint until the destination is reached. The Scout should also be able to tell the instructor that the microprocessor contained in the GPS receiver will also calculate the heading and distance to each waypoint based upon user selected parameters as well as the total distance to be covered, total time of the route, speed, distance travelled, time remaining enroute and cross track error. The Scout should also be able to explain that the prudent navigator does not rely on one source of navigational information but must use all information available to him or her.

The Scout should then plot a route of a minimum of two legs on the navigational chart and enter the latitude and longitude of the departure point, one intermediate course change and the destination into the GPS unit or other GPS dependent Electronic Navigation System. He or she should navigate the unit's primary vessel along that route, keeping a proper log and proper chart work including DR positions and fixes by GPS until the vessel arrives at the intended destination. Once the vessel has arrived at the intended destination, the Scout has fulfilled this section of the requirement.

Section f. Radar Navigation: For this section the Scout must be able to discuss the methods of taking a radar fix.

Materials: Navigational Chart
Radar (if available)
0.5mm Mechanical pencils
Triangles/Course Plotter/Parallel Rules
Dividers
Drawing Compass or dividers fitted with a pencil lead.
White Eraser
Pub. 1310 Radar Navigation and Maneuvering Board Manual

Procedure: The instructor should be familiar with the primary means of establishing a radar fix. If not, he or she should familiarize him or herself with page 190 of the Sea Scout Manual, pages 738-745 of Chapman, pages 138-139 of Dutton's, Chapter 13 of Bowditch or pages 161-164 of the Radar Navigation and Maneuvering Board Manual.

The instructor should teach the Scout about the limitations and advantages of Radar navigation. Its advantages include tis extreme usefulness in poor and limited visibility and that it is highly accurate for determining distances and less so in determining bearings to an object. Another limitation is that the Radar operator must be highly practiced and familiar with the radar being used so that objects can be readily and accurately identified.

There are four basic methods used in establishing a fix by radar and they are:

a. Ranges from two or more objects.
b. Range and bearing from one object
c. Bearings from two or more objects
d. Tangential bearings from a single object.

The Variable Range Marker and Electronic Bearing Line on most modern radars are used to take bearings much in the same way that visual bearings are taken. With ranges, the range is marked on the chart as an arc and an intersection of a range and a bearing or two or more ranges and bearings provides a fix. Care must be taken to accurately mark ranges on the chart. Once a fix is established, it is marked with a triangle and labeled with the time and the word RADAR. This should be demonstrated on the vessel's radar of equipped and the instructor should provide a few problems for the Scout to plot on the chart.

Annotated Bibliography

Maloney, Elbert S. and Charles F. Chapman Chapman Piloting and Seamanship. 65th ed. New York: Hearst, 2006

Chapman is by far the most used reference on piloting and seamanship in use in the United States today. It contains information on piloting, seamanship, boat handling, safety and has a number of useful appendices.

Cutler, Thomas J. Dutton's Nautical Navigation. 15th ed. Annapolis: Naval Institute Press, 2004

Dutton's is the standard textbook on piloting and navigation used in the United States Naval, Coast Guard and Merchant Marine academies. Often the explanations in Dutton's are more detailed, yet clearer than those in Chapman.

Bowditch, Nathaniel. Pub. No. 9: The American Practical Navigator: An epitome of navigation. Bethesda, MD: National Imaging and Mapping Agency, 2002

Bowditch is THE BIBLE when it comes to piloting and navigation in the United States. It is the standard reference from which all others are drawn. A copy is carried on every vessel in the United States Navy, Coast Guard and Merchant Marine and it should be on your bookshelf as well. Besides the basics of piloting and navigation, Bowditch contains information on celestial and electronic navigation, gyrocompasses, magnetic compass compensation, buoyage, charting and a host of other subjects.

Pub No. 1310: Radar Navigation and Maneuvering Board Manual. 7th ed. Bethesda, MD: National Imagery and Mapping Agency, 2001

Pub. 1310 is the standard reference when it comes to radar navigation and collision avoidance. All military and merchant marine services in the United States use it as a textbook and reference when it comes to radar navigation.

Chief of Naval Operations. OPNAVINST 3100.7C Washington, DC, Department of the Navy, 2014

This is the standard reference for keeping a ship's log for the United States Navy. It is used as a model, with modifications and deletions for the Coast Guard and the United States Merchant Marine.

Sea Scout Manual. 11th ed. Irving, TX: Boy Scouts of America, 2010.

The Sea Scout Manual is the reference for the Sea Scout program in the United States. While it outlines requirements, advancement and program, it is far from complete or accurate. There are non-standard abbreviations and practices used throughout. While it is a good starting point, I highly suggest that it be supplemented by one of the above cited references.

Sources for Materials

Below is a list of suggested sources for materials. It is by no means exhaustive or comprehensive but should serve as a starting point for those wishing to assemble, update or replenish their navigational references and materials. Basic piloting tools: plotters, triangles, dividers, nautical slide rules etc.: I usually go to West Marine, Celestaire Landfall Navigation, Safe Navigation Way Point or Maryland Nautical.

West Marine: www.westmarine.com
Celestaire: www.celestaire.com
Way Point: www.waypoints.com
Maryland Nautical: www.mdnautical.com
Landfall Navigation: www.landfallnavigation.com
Safe Navigation: www.safenavigation.com
Maryland Nautical and Way Point have print on demand charts and Maryland Nautical carries the NOAA Training charts.

Chart No. 1 is available for free download at:
http://www.nauticalcharts.noaa.gov/mcd/chartno1.htm

Light Lists are available for free download at: http://www.navcen.uscg.gov/?pageName=lightLists

US Coast Pilots and updated electronic charts are available for free download at:
http://www.nauticalcharts.noaa.gov/staff/charts.htm

Chapman, Dutton's and Bowditch are available at www.amazon.com but they may not always be in stock or be available at the best prices.

An online copy of Bowditch can be found here:
http://msi.nga.mil/NGAPortal/MSI.portal?_nfpb=true&_pageLabel=msi_portal_page_62&pubCode=0002

International charting symbols and standards can be found at:
http://www.sailingissues.com/navcourse4.html

The Radar Navigation and Maneuvering Board Manual can be found here:
http://library.csum.edu/navpubs/Pub1310.pdf

The standards for logbooks can be found here:
http://doni.daps.dla.mil/Directives/03000%20Naval%20Operations%20and%20Readiness/03-100%20Naval%20Operations%20Support/3100.7C.pdf

0.5 #2 mechanical pencils, pens, white erasers and paper can be purchased at www.amazon.com, www.officemax.com, www.staples.com or www.officedepot.com. For teaching and practical piloting on the boat, I prefer the Bic 0.5 disposable pencils and Bic Stick pens. They are inexpensive and can be purchased in large quantity.