TWELFTH WEEK. G.B.Todd,RM1c.
Navigation and Radio Compass.
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QUESTION #1. What are the principle uses that a Chief Radioman will have for a knowledge of navigation?

ANSWER #1. The principla uses that a chief radioman will have for a knowledge of navigation are as follows:

(1) Ability to correct radio bearings for curvature of the earth.

(2) An accurate knowledge of piloting and charts, in order to be able to pick out the proper radio stations and plot their bearings correctly.

(3) Ability to lay off courses and speeds on a chart and pick off positions (latitude and longitude) correctly. This knowledge is particularly valuable in contact reports, and in sending out positions, following an emergency involving a possible S O S signal giving the ships position.

(4) A knowledge of chart catalogues, chart numbering, and method of stowage, in order that a desired chart may be gotten out quickly.

(5) The ability to use soundings and character of the bottom to ascertain the position of the ship in thick weather.

(6) A knowledge of the use of soundings to check the accuracy of radio fixes.

(7) A knowledge of variation and deviation, in order to convert compass courses, or vice versa.

QUESTION #2. Describe a Navy Standard liquid compass.

ANSWER #2. The Navy Standard liquid compass has a card of tinned brass, with the outer rim graduated in degrees to enable the steersman to steer any given course. It is mounted on a pivot, in a bowl, and the bowl is filled with alcohol. Resting on the liquid keeps the compass card from wabbling or moving too quickly. The magnet system of the compass card consists of four cylindrical bundles of steel wires. These wires are laid side by side and magnetized as bundles between the poles of a powerful electromagnet. Then they are placed in cylindrical cases and sealed. The bundles are attached to the compass card with the needles parallel to the north and south diamete of the card.

QUESTION #3. Where should the standard compass be located? Why?

ANSWER #3. The standard compass should be located on the fore-and-aft line of the ship. It should be as far away as possible from all movable iron and from the influences of dynamos or electrical currents. It should be easily accessible and must be near enough to the steering

ANSWER #3. Continued.

compass to allow easy check. It should be mounted so as to afford a clear view all around the horizon in order to permit taking bearings and azimuths.

QUESTION #4. What is a binnacle? How located? Where are the correcting magnets placed?

ANSWER #4. Binnacles are stands in which compasses are mounted. The binnacle must be securely fastened to a rigid deck, in such a position that the "lubber's line" on the compass centered in the binnacle will indicate the direction of the ship's head. The correcting magnets in the hollow chamber, are mounted in trays which can be raised or lowered, independently of each other, by a screw moved by bevel gears. The mechanism permits a 12-inch travel of the trays. A scale on the side of the trays, graduated in inches shows their position in the binnacle. The correcting magnets are held in trays by spring closing devices. Each tray can hold six magnets, three on each side of the vertical. The trays are horizontal. There are two sets of trays, one set extending athwartships, and one in a fore-and-aft direction in the binnacle. The correcting appliances on the arms extending from the binnacle are spheres of soft iron secured to the arms by screw bolts. The centers of the spheres are in the same horizontal plane as the compass magnet. The spheres can be moved in and out on the arm. The distance from the center of the compass is indicated by a scale of inches on each arm.

QUESTION #5. Explain how to take a bearing with a pelorus.

ANSWER #5. The pelorus consists of a flat circular metallic ring, mounted in gimbals upon a vertical standard at some point on board ship affording a clear view for taking bearings. The inner edge of this ring is engraved in degrees, the 360° and the 180° marks indicating a fore-and-aft parallel to the keel of the ship. Within this ring a ground-glass dial is pivoted concentrically. This ground-glass dial has painted upon it a compass rose divided into points and subdivisions, and into degrees. This dial is capable of revolution, but may be clamped to the outside ring. Pivoted concentrically with the flat ring and the glass dial is a horizontal bar carrying at both of its extremes a sight vane or mounted upon the bar and parallel to it, a telescope containing cross wires. This sight vane bar can be clamped in any position independently of the ground glass dial which can be moved freely beneath it. An indicator showing the direction the sight vane bar is pointing can be read upon the compass card on the glass dial. The instrument is used to take bearings of distant objects and at times may be more conveneint for that purpose than the standard compass on account of the better view commanded by its position, as well as because it may be made to eliminate compass errors from observed bearings, thus reducing the bearing observed to magnetic or true bearings. If the dial be set allowing for both deviation and variation of the compass then all bearings read will be true. It should b

ANSWER #5. Continued.

be noted however that the bearings taken by pelorus will be accurate only when the ship is on her exact course. For this reason when taking a bearing by pelorus at the same time note the heading by standard compass, and clamp the sight vane. Then move the glass dial until the direction opposite the deadahead mark is the same as that noted by the standard compass, the bearing observed (corrected for the variation and for the deviation of the heading at the instant of observation) will be the true bearing.

QUESTION #6. Explain how to take a bearing with the azimuth circle of: (a) Terrestial object; (b) the sun.

ANSWER #6. An azimuth circle is a circular piece of metal fitted with a pair of sight vanes and a system of mirrors and prisms, fitted snuggly over the top of the compass bowl, so that it can be moved around the edge easily. To take a bearing with the azimuth circle on a terrestrial object: Rotate the circle until object comes into sight thru the sight vane, then glance at the mirrored reflection of the compass card reading, which is brought into the field of view, and the reading will be the bearing from the ship's head, after the compass reading is deducted. For observing azimuths of the sun, advantage is taken of the brightness of that body to deflect a pencil of light through these prisms and mirrors upon the card in such a way as to indicate the bearing. To take a bearing of the sun, the mirror on the circle must be tilted back and forth until the sun's rays are reflected into the prisms on the opposite side of the circle. A pencil of light will then be seen on the compass card. Where this pencil cuts the card, is the sun's compass bearing, or azimuth.

QUESTION #7. What is a compass error? A meridian? A parallel?

ANSWER #7. The difference between the true north, or south, and the direction in which the compass points, is known as the compass error. Compass error is divided into two classes one, the error caused by the effect of the earth's magnetism itself on the compass magnets, called "variation" and the other, the error caused by the iron in the ship magnetized by the earth's magnetism and by local influences, called "deviation." Variation and deviation are combined algebraically into the compass error. A meridia is a circle passing through the true poles of the earth and is called a meridian of longitude. A parallel is a circle parallel to the equator and is called a parallel of latitude. All navigational work is based on these true meridians of longitude running north and south and true parallels of latitude running east and west. For that reason all courses must be true. The magnetic compass seldom points to the true north or south due to the variation and deviation defined above.

QUESTION #8. What is a magnetic meridian?

ANSWER #8. The direction in which the compass magnets point is called the "magnetic meridian". Except at points along the "line of no variation" the "magnetic meridian" never corresponds to the true meridian, but makes an angle to the east or west of the true meridian equal to the variation of that locality.

QUESTION #9. Why does not the compass magnet point to the True North?

ANSWER #9. The earth's magnetic poles do not agree in location with the earth's true poles (the imaginary ends of the earths axis of rotation) and, since compass magnetis, unaffected by any outside influence, are drawn by the earth's magnetism toward the earth's magnetic poles, it is apparent that the compass magnets do not point to true north or south, but to magnetic north or south.

QUESTION #10. What is variation?

ANSWER #10. The amount that the compass magnets point away from the true poles is called "variation" and is caused by the magnetic property of the earth itself, since the compass magnets will point toward the magnetic poles of the earth, which are not in the same place as the true poles.

QUESTION #11. What is deviation?

ANSWER #11. A ship is made of iron or steel, magnetic material, which comes under the influence of the earth's magnetism and under local magnetic influences, and is thus given the properties of a magnet. This magnetized material on the ship then exerts its magnetic influence on the ship's compass magnets. We have seen that under the earth's magnetic influence alone the compass magnet lies in the "magnetic meridian." But on board ship, under the ship's local magnetic influence, as explained above, the compass magnet is drawn from the magnetic meridian by the ship's local magnetic influence. The amount that the compass magnet is drawn from the magnetic meridian by the ships local magnetic influence is called "deviation." Deviation, unlike variation, differs in amount for different compass headings. It also changes in different localities.

QUESTION #12. How do you determine the variation and deviation to be applied to any particular course?

ANSWER #12. Charts published by the Hydrographic Office of the Navy show the variation in all localities. There is a general chart, H.O.No.2406, which shows the variation thruout the world. In addition, each chart published shows the variation in the particular area charted. The variation keeps changing yearly and all charts show this yearly change. The navigator in noting the variation in a particular locality must be careful to note also the yearly change. This yearly change must be multiplied by the number of years from the date the chart was published. Variation is applied with the proper sign and is the same for all headings of the magnetic compass.

ANSWER #12. Continued.

Deviation changes for every ship, every compass, every heading, and every locality. To find the error of the compass due to deviation, the navigator "swings ship" That is, with the ship under way, which is the usual procedure in the Navy, it is steadied on each of the twenty-four 15° points of the compass card, and the error on that heading due to deviation noted by one of the standard methods. Before starting to swing it is necessary to have the ship on an even keel and to have all movable iron in the vicinity of the compass secured in its usual position and the compass centered in the binnacle. The ship should be steadied for at least three minutes on each heading to allow the ship's magnetic influence to exert its effort upon the compass magnets. It is possible to find the deviation on all compasses at the same time by stationing a man at each compass to read that compass heading upon a designated signal from the navigator at the standard compass. There are four methods for finding deviations by swinging ship: (1) By reciprocal bearings. (2) By ranges. (3) By a distant object. (4) By bearings of the sun. One method will be described here: By bearings of the sun. This method requires that a bearing of the sun be observed, by using the azimuth circles as explained previously, and that the exact time of the bearing be taken by a chronometer or watch. By a method which will be explained later the true bearing of the sun at the same instant can be calculated. By applying the variation of the locality to the sun's calculated true bearing the magnetic bearing of the sun is obtained. Then the difference between the sun's magnetic bearing and the compass bearing of the sun gives us the compass deviation on the particular heading of the ship it is necessary in this method, as in the others, to determine the deviation on every 15° point of the compass.

QUESTION #13. Define: True, magnetic, and compass bearings and courses.

ANSWER #13. There are three methods by which courses or bearings may be expressed: (1) True, when they refer to the earth's geographical meridian; (2) Magnetic, when they refer to the earth's magnetic meridian (these bearings must be corrected for "variation" in order to make them true); (3) Compass, when they refer to the angular distance from the true north indicated by the compass on a given heading of the ship (these bearings and courses must be corrected for the deviation on that heading for conversion to magnetic, and for both deviation and variation for conversion to true).

QUESTION #14. True course 275° variation 10° W deviation 7° E. What is the compass course? The magnetic course?

ANSWER #14.

True course........275°
Variation.......... 10° W (adding)
Magnetic course....285°.......Ans.
Deviation.......... 7° E (subtracting)
Compass course.....278°.......Ans.

QUESTION #15. Compass course 187° variation 6° E deviation 1.5° W What is the true course? The magnetic course?

ANSWER #15.

Compass course........	187°	
Deviation.............	1.5°	W (subtracting)
Magnetic course.......	185.5°....Ans.	
Variation.............	6 °	E (adding)
True course...........	191.5°....Ans.	

QUESTION #16. Ship on course 97° per compass. The navigator takes a bearing of a light house and finds it to be 142° per compass. Variation 9° W, deviation 2° W, on that course; what is the true bearing of the light?

ANSWER #16.

Compass Bearing.......	142°	
Deviation.............	2°	W (subtracting)
Magnetic bearing......	140°	
Variation.............	9°	W (subtracting)
True bearing..........	131°......Ans.	

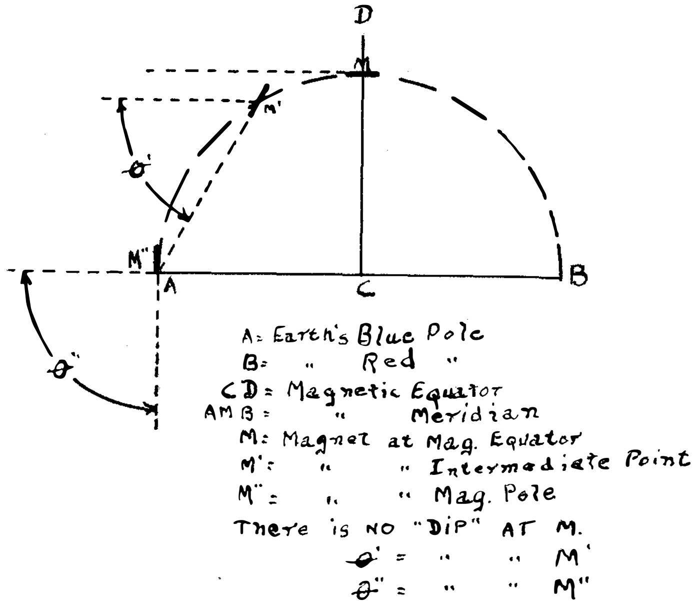
QUESTION #17. Navigator gets the sun bearing 126 per compass at 9:20 AM, when the ship is headed 45° per compass. The true bearing of the sun is forwarded by computation to be 129° at that time and place. The variation is known to be 5° E. Find the total compass error and the deviation

ANSWER #17.

True bearing..........	129°	
Variation.............	5°	E (subtracting)
Magnetic bearing......	124°	
Compass bearing.......	126°	(subtracting)
Deviation.............	-2°	= 2° W....Ans.
Variation.............		5° E
Total compass error...		3° E....Ans.

QUESTION #18. Take a magnet and suspend it at a point equally distant from each of its own poles, so that its ends are free to move up and down around that point of suspension. First place this magnet thus suspended at the"magnetic equator." What position will it assume? We find that it will lie horizontally because being equally distant from each pole of the earth it is acted upon equally by the magnetic forces of each pole. Now move it toward either pole of the earth, but always keep it moving along the "magnetic meridian" to a certain position. The magnet has been moved nearer to the blue pole in the Northern Hemisphere, and therefore that blue pole exerts more influence on the red end of the magnet than the south pole does. The line AM' on the figure represents direction of "total magnetic force" of the earth's blue pole. The red end of the magnet points toward it while lying in the magnetic meridian and makes an angle with the horizontal shown in the figure θ and called the "dip". The "dip" varies between the magnetic equator and the magnetic pole as shown, increasing toward the latter, so that when the pole is finally reached as shown at M' the magnet is standing vertically and the "dip" is a maximum.

ANSWER #18. Continued.



QUESTION #19. What is "induction" in magnetism? What differentiates hard iron from soft iron as regards induced magnetism?

ANSWER #19. When a piece of unmagnetized iron or steel is brought within the field of a magnet, the former becomes a magnet. It continues to remain so as long as it remains within the field of the influencing magnet. The magnetism that is acquired in this manner is said to be "induced." Another law of magnets states that: "Induced magnetism is of the opposite polarity to the kind producing it," which means, that if an unmagnetized piece of iron is brought near the blue pole of a magnet the former will have red magnetism induced in it, and likewise if it is brought near a red pole it will have blue magnetism induced in it. The softer the metal the more quickly it acquires this induced magnetism and the more quickly it loses its magnetic properties when the inducing magnet is withdrawn. Hard metal is slow to acquire magnetic properties under influencing , but when once magnetized it tends to retain this induced magnetism longer after the influencing magnet is withdrawn. Therefore in considering the different classes of metal on board ship it is customary to designate as "hard iron" that which acquires its induced magnetism slowly, but retains it after the magnetic influence is withdrawn; and as "soft iron" that which quickly acquires magnetic properties under inducing influences and loses them quickly when these influences are withdrawn. Furthermore, if a piece of iron or steel, while possessing this induced magnetism, is subjected to hammering, twisting, or any mechanical violence, the induced magnetism is made to assume a permanent nature.

QUESTION #20. State the effects which go to make up deviation on a ship.

ANSWER #20. Deviation, the amount the compass magnet is drawn away from the magnetic meridian, is made up of the following effects: (1) Subpermanent magnetism; that is; the magnetism which was induced in the ship while it was being built, which becomes of a permanent nature after the ship has been in commission for a short time. (2) Transient magnetism induced into the vertical soft iron of the ship by the vertical component of the earth's total magnetic force, which varies with the magnetic latitude, being the greatest at the poles where the vertical component is greatest. (3) Transient magnetism induced in the horizontal soft iron of the ship by the horizontal component of the earth's total magnetic force, which varies with the magnetic latitude.

QUESTION #21. Name the classes of deviation. State what causes each and how in general each force causing deviation is neutralized.

ANSWER #21. There are three classes of deviation. The causes of each and the manner of neutralizing will be taken up separately:

Semicircular deviation. Is so called because it is of one kind, east or west; in one semicircle, or 180 degrees of the compass; and then as the ship swings in azimuth, changes and becomes of the opposite kind in the other semicircle, or the other 180° of the compass. The points of change, or of zero semicircular deviation are opposite each other and usually correspond with the headings on which the ship was built and its complement To illustrate, in a ship headed north while being built the semicircular deviation should be zero on the north point of the compass, a maximum westerly on the east point of the compass, a zero again on the south point of the compass, and a maximum easterly on the west point of the compass. It is fairly regular. Semicircular deviation is produced by the horizontal component of the "subpermanent" magnetism in the ship, and by the magnetism induced in the vertical soft iron of the ship by the vertical component of the earth's total magnetic force. Magnets are used to correct the subpermanent magnetic effect. For Navy compasses, bundles of small magnets are placed in trays inside the binnacle beneath the compass. These trays can be moved up and down in the binnacle to vary their distance from the compass magnet. Their position in the binnacle depends on the strength of force tending to draw the compass magnet out of the meridian. One set is placed in the fore-and-aft line of the ship, and the other set in the athwartship line of the ship. To correct the transient magnetism induced in the vertical soft iron of the ship, a soft iron corrector is used. It is called a Flinders bar, made up of a bundle of soft iron rods contained in a case secured in a vertical position with its upper level with the plane of the needle. After such correcttion semicircular deviation does not change with the change of latitude.

ANSWER #21. Continued.

Quadrantal deviation. Is deviation which is of one kind in one quadrant, of the opposite kind on the next and so on around the compass. It is regular in character and is generally easterly in the NE and SW quadrants and westerly in the NW and SE quadrants. Quadrantal deviation is produced by the effect of the horizontal magnetism induced in the soft iron of the ship by the horizontal component of the earth's magnetism on the compass. This deviation does not change with the magnetic latitude. The forces causing quadrantal deviation are neutralized by the use of soft iron correctors, usually spheres. These spheres are placed one to starboard and one to port on the athwartship line of the compass passing through the center of the compass. In view of the fact that quadrantal deviation does not change with latitude, it follows that if these correctors are properly placed and the forces causing this deviation are neutralized in one latitude, they should remain neutralized.

Constant deviation, as the name implies, is the same for all headings. The constant error is imaginary, to a large extent, if the compass is on the center line, and arises from instrumental errors, incorrect readings misplaced lubbers line, etc. If the compass is not on the fore and aft line of the ship, however, the constant deviation is real. No attempt is made to correct constant deviation.

QUESTION #22. What is "apparent time?" "Mean time?" What is the difference between them called? Where may its value be found?

ANSWER #22. The unit of time is the day. A day may be defined as the interval which elapses between the instant the sun passes over the meridian of a place, or the celestial meridian of that place, until it recrosses the same meridian. Such time is called "solar time". The sun which we see, the true sun, does not travel at a constant rate in its apparent annual trip around the earth Some days it travels 57' and other days it travels 61' Likewise the fact that its apparent path lies at an angle to the earth's equator makes its apparent motion irregular. No clock mechanism has yet been made to record this irregular motion. In reckoning ordinary time, a fictitious sun, called the "mean sun" with a constant daily rate and traveling in the equatorial is chosen. The clocks aboard keep the time of this fictitious sun. If the motion of the mean sun is considered we refer to the time as mean time and if the motion of the true sun is considered the time is called "apparent time" The time of a particular locality on the earth's surface is called local time and is "local apparent time (L.A.T.)" or local mean time (L.M.T.)" depending on the sun used. In all navigation-al work where the sun is the celestial body observed, the time used is the time of the true sun or apparent time. The difference between the two is called the "equation of time. The value of the equation of time will be found tabulated in the Nautical Almanac for each two hour

QUESTION #23. What is standard time? Zone time? How are zones named?

ANSWER #23. Meridians 15° apart, through 180° each side of the meridian of Greenwich (GT) are called "standard meridians." The time corresponding to each of these meridians is called "standard time." The standard time of each standard meridian is kept on board ship in a zone extending 7½° each side of that meridian. Thus the time of the seventyfifth meridian is kept in the zone from longitude 67½° to 82½° and the time of the fortyfifth meridian from 37½° to 52½°, etc. These zones of time are named to agree with the number of hours of longitude the meridians through their middles are east or west of Greenwich. They are plus or minus depending on whether they are west or east, respectively, from Greenwich. Thus, the time of the zone of the seventy-fifth meridian in west longitude is "Plus five" and a ship keeps "Plus five" time from 67½° to 82½° W. It will be remembered that 15° of longitude equals one hour of time. Also, that the sun in its apparent motion travels once around the earth each 24 hours from east to west.

QUESTION #24. What is the Greenwich meridian?

ANSWER #24. The Greenwich Meridian is the meridian of 0° longitude. It gets its name from the observatory at Greenwhich, England. All longitude and time are reckoned from the Greenwich meridian. The chronometer reads XII when the mean sun is over the meridian at Greenwich, since the time kept by the chronometers on board ship is the mean time of the Greenwich meridian.

QUESTION #25. Explain how to find C-W.

ANSWER #25. Navigators are supplied with chronometers from which to obtain the Greenwich time. Practically all chronometers have errors, and dail rates, gaining or losing so that in order to get the correct Greenwich time, the chronometer error and daily rate must be known. Likewise the clocks aboard do not keep exactly correct time. Therefore to simply apply the longitude in time to the time as shown on the clock does not give the correct G.C.T. To get the correct G.C.T. it is necessary first to compare the watch and the chronometer times at the same instant. The navigator reading the chronometer gives "mark" at a certain time by the chronometer and another observer on the watch notes the reading of the watch at that instant. The difference is shown as C-W (chronometer minus watch). Now if the watch time is added to the C-W it can be seen that the sum is the chronometer time. Then if the chronometer error (the amount the chronometer is slow or fast) is applied to this chronometer time, the correct Greenwich time is obtained.

QUESTION #26. Explain how to find the correct G.C.T. and date.

ANSWER #26. See next sheet.

ANSWER #26. Continued.

To find the correct G.C.T. any date:

(1) Express the ship time in hours, minutes, and seconds, from zero hours at midnight, through the 24 hours of the day; that is, add 12 hours to all p.m. times as shown on the clock.

(2) To this local time add the longitude in time if west. The result will be the G.C.T. If the sum is greater than 24 hours, subtract 24 hours from the total, and the difference is the G.C.T. on the succeeding date.

(3) If the longitude is east, subtract the longitude in time from the local time in (1). The difference is the G.C.T. If the longitude in time is greater than the local time, add 24 hours to the local time, and the difference between that sum and the longitude equals the G.C.T. of the previous date.

QUESTION #27. Explain how to find the true azimuth. (State books or publications used and the steps necessary in the solution of the problem).

ANSWER #27. To find the true azimuth or bearing of the sun, it is necessary to refer to tables issued by the hydrographic office, in which data which the navigator has at hand are tabulated, with the corresponding azimuths. The tables necessary are the American Nautical Almanac for the current year and the Hydrographic Office Publication No. 71, Azimuths of the Sun. The use of these tables will be explained. Look at the Nautical Almanac for the current year. It will be seen that under the "heading" sun there is tabulated for each two hours of each day of that year the suns "declination" and "equation of time." The latter has been explained. Declination may be defined briefly as follows: When the sun is north of the celestial equator the sun is said to have "north declination" and when it is south of the equator the sun is said to have "south declination." The sun has north declination from March 21 when the days and nights are equal through June 21 when the days are longest in the Northern Hemisphere, to September 21 when the days and nights are equal again. It has south declination through the remaining half of the year. It is this distance north and south of the celestial equator, the angular value of the declination which is tabulated in the Nautical Almanac for each day of the month thru the year. This is marked positive when the declination is north and negative when it is south. It will be noted that the values are tabulated for G.C.T. so to find the correct value it will therefore be necessary to find the G.C.T. of observation as already explained. Now turn to the table of "Azimuths of the SUN" It will be seen that the azimuth is tabulated for each degree of suns declination and for each 10 minutes of local apparent time. Also that the first half of the book contains tables giving the azimuth when the lati-

ANSWER #27. Continued.

tude and declination are the same name and the second half, tables giving the azimuth when the declination and the latitude are of different names. Therefore as seen, the true azimuth of the sun depends upon four elements: (1) The apparent time, which is the exact local apparent time of the observation of the sun. (2) The declination of the sun at that particular instant. (3) The latitude and longitude of the place in which the observation is taken. (4) The fact of whether the latitude and declination are of the same or opposite names.

QUESTION #28. Describe the procedure by progressive steps in the practical compensation of the compass.

ANSWER #28. The order of compensating is as follows: (1) Semicircular deviation (2) quadrantal deviation. To compensate for semicircular deviation: (1) Steady the ship on any magnetic cardinal point, north, east, south, or west. Put the permanent magnet in the trays and bring the compass to read this magnetic course by raising or lowering these trays. If heading north, correct deviation by using athwartship magnets, putting red end to starboard for easterly deviation and red end to port fo westerly deviation, and the reverse on south. If heading east correct by using fore-and-aft magnets, putting red end forward for easterly deviation and aft for westerly, and the reverse if heading west. (2) Steady the ship on the adjacent magnetic cardinal point and correct the compass heading by permanent magnets to mak it correspond therewith by the same rules as above. (3) Steady the ship on the reverse course of (1). Halve the deviation shown on that reverse heading. (4) Steady the ship on the reverse course of (2). Halve the deviation on this reverse heading. (5) Put the ship on the original course, and recheck that deviation. That should complete the correction for semicircular deviation. Quadrantal deviation is corrected by the soft iron spheres already mounted on the binnacle. Head the ship northeast magnetic. Suppose it is now 8:50 L.A.T. and the sun's magnetic azimuth is 105° 36'. Turn the azimuth circle until the angle between the reflecting prism opposite the mirror and the lubber's line on the edge of the compass bowl is 60½°. Then swing the ship until the sun's reflection is in the slot of the reflecting prism. The ship is then heading 45° magnetic Hold it on that heading by the steering compass as already described. Move the soft iron sphere in or out to bring the compass to read 45° or as near as possible Swing the ship to the different intercardinal points, or magnetic headings, SE, SW and NW and move the correctors until there is an equal amount of deviation, not more than ½° if possible, on each of these headings. The quadrantal disturbing forces should then be corrected.

QUESTION #29. What is meant by "swinging ship for residuals?"

ANSWER #29. See next sheet.

ANSWER #29. Continued.

After the compass has been compensated for semicircular and quadrantal deviation, there is still some deviation left due to the constant deviation and other causes. To determine this the navigator swings ship for residuals. To do this the ship is swung through the 36)° of the compass. It is steadied on each 15° compass heading long enough (say, 2 to 4 minutes) to allow the compass to settle on that course and to obtain an accurate bearing of the sun. The result of these observations are tabulated.

QUESTION #30. Where is the correct deviation table kept? Describe in general terms the gyro compass; give advantages and disadvantages as compared to the magnetic compass.

ANSWER #30. The correct deviation table is made in triplicate and each copy pasted on a small board for use, as follows: One in chart house, One on bridge, and One in Navigator's notebook.

Principle of the gyro-compass. When a wheel is spun in space it will keep spinning in the same direction, unless it is acted upon by some external force. The gyro compass wheel is so mounted that the only forces that can act upon it are the rotation of the earth on its axis and the forces of gravity. The result of the action of these forces is such that the axis of the gyro-compass wheel always points in a north and suuth direction. The master gyro-compass itself is kept below decks, behind armor. By means of electric connections, compass cards called repeaters can be mounted in any desired part of the ship, and are made to follow exactly the movements of the master gyro-compass card. These repeaters are used on the bridge, at the auxiliary steering stations, fire-control stations, and whereever else needed. The decided advantage of the gyro-compass is that it points to the true or geographical north instead of to the magnetic north, so the gyro compass need not be corrected for deviation, because it has none. The disadvantage is that it depends on an electric current to supply the rotation, and, would be useless if this current were cut off.

QUESTION #31. What is piloting? Why is extreme accuracy necessary?

ANSWER #31. Piloting is that part of navigation which has to do with conducting a vessel through channels, along coast lines, and into harbors where there are terrestrial aids to navigation, and where the water is of such depth that the position must be constantly checked and courses frequently verified and changed. Extreme accuracy is necessary because one inaccurate position, or one wrong course, while piloting, may put the ship on the rocks.

QUESTION #32. Who issues charts to ships of the Navy?

ANSWER #32. The Hydrographic Office in Washington issues all the charts to the Navy. They are marked to show the office publishing them, as follows: Hydrographic Office, H.O. COast Survey, C.S.? and British Admiralty, B.A.

QUESTION #33. How are charts arranged? What are chart portfolios? What is a chart catalogue? Describe how you can find the chart you want from the catalogue.

ANSWER #33. All charts issued are arranged as far as practicable in geographical sequence, are numbered consecutively, and are divided into portfolios. Each portfolio contains about 100 charts. The consecutive numbers in each portfolio begin with the even hundred. For instance a chart numbered 720 is in portfolio No. 7. General charts are in portfolio No.1. Charts are of three kinds general, sheet, and harbor. Portfolios are numbered consecutively. Certain stations and classes of ships have certain portfolios assigned to them. For example the battleships of the Scouting Fleet are assigned portfolios Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9, 40, 44. Atlantic destroyers have the same allowance except portfolios 2 and 44. Portfolios 1-38 contain charts covering the entire world; 39, 40, 41, 42 contain selected charts of certain areas. Portfolios with numbers above 42 contain charts for use of wardroom, commanding, and flag officers. In addition to their consecutive number, charts also have a publication number which is shown in the left upper and right lower corners. Every chart issued is catalogued as follows:

1267 - H.O. - 2181 - Anchorages and Bays in the Gulf of California.

Entrance to the Estero de Agiabampo; pulpito, and Mangles Anchorages, etc.

There are four such catalogues, one for each of the four stations, Atlantic, Pacific, European, and Asiatic. It will be seen that the consecutive number, the office issuing the chart, the publication number and title are listed for all charts. Catalogues contain an "index chart" from which can be found the portfolio numbers covering all the areas of the world. By referring to correct the desired chart can be found.

QUESTION #34. Define General Chart, Sheet Chart, Harbor Chart.

ANSWER #34. General charts comprise an entire ocean, or a large part of it. Sheet charts are parts of general charts, on larger scales. Harbor charts show in detail the entrance to all large harbors.

QUESTION #35. What is a Mercator Chart; Describe how you lay a course and measure distance on a mercator chart.

ANSWER #35. The charts most generally used in the Navy are constructed on what is known as the "Mercator projection" (So named for its originator, Gerad Mercator, of Flanders). On these, the meridians are drawn parallel to each other and perpendicular to a straight line, representing the earth's equator. All degrees of longitude are equal, but the degrees of latitude vary in length on this projection. They increase in length from the equator to the poles, in the same proportion

ANSWER #35. Continued.

as the longitude decreases on the earth. The big advantage of this type of projection is that on it all courses appear as straight lines. Each chart contains numerous "compass roses" or circles of verying diameters, whose circumferences are divided into 360°. The zero degree marks point to true north. Each 10° from 10 to 350 is marked on the circumference.

To find a course on a mercator chart. Lay down a parallel ruler so that its edge joins the point of departure and point of destination. Move the ruler parallel to itself until the same edge passes through the nearest "compass rose". The degree mark, where the edge passing through the center of the rose cuts the circumference, represents the course. Likewise to put a certain course on the chart from a given point, place the edge of the parallel ruler so as to pass through the center of the compass rose and the degree mark on the circumference representing the desired course. Then move the ruler parallel to itself until the same edge passes through the given point and draw a light line on the chart in the desired direction. The relation between true and compass courses must be constantly remembered. Likewise the fact that the variation changes in different areas must be considered.

To measure a distance on the mercator chart. Since the unit of measure, the mile, or minute of latitude, has a different value in every latitude, it becomes necessary to know the mean latitude between the point of departure and the point of destination before the correct distance can be measured. This is called the "middle latitude." To measure a distance, take off that distance with a pair of dividers and measure it along the graduated latitude scale on the chart, so that the middle of the line representing the distance will be in the middle latitude between the points joined by the line. As stated, one minute of latitude at the middle latitude between the points equals 1 sea mile.

QUESTION #36. What are pilot charts? What information do you find on one of them?

ANSWER #36. Pilot charts are special general charts issued by the Hydrographic Office to all ships without request. There are six such charts published, each representing a particular ocean area. Four of these are issued monthly and two quarterly. They contain the latest available information regarding predicted wind and weather, also positions of derelicts and icebergs. Currents to be expected are shown in dotted lines, and their strength in knots per hour is shown in printed digures alongside the arrows showing their direction. For every 2½° square (150 miles in latitude) there is a small circle showing the prevailing winds in that area. (A footnote explains their use.) Traffic lanes, with distances, are shown in full lines. Radio-compass stations are listed on the chart. The information these charts contain is invaluable and the navigator should consult them frequently.

QUESTION #37. What is a sextant? Stadiameter? Drafting machine?

ANSWER #37. While the sextant may be considered as a navigational instrument for use in deep sea navigation only it has its uses during piloting. The extreme accuracy with which both horizontal and vertical angles may be measured with the sextant gives the navigator a handy instrument for checking his position. If the height of an object is known in yards, the vertical angle between the base and the top of that object may be measured with the sextant from the ship. Then either by plotting or by the solution of the triangle the distance in yards from the ship to the object may be found. In measuring vertical angles, accuracy requires that the angle at the base of the vertical object equal 90°. Likewise if the length of an object is known the distance from it may be determined by taking the horizontal angle with the sextant. This is the more common use of the sextant in piloting. The sextant thus replaces the compass bearings taken on the pelorus or with the azimuth circle. Angles taken with the sextant are more accurate than those taken by the latter methods. To take horizontal angles the sextant is held horizontally instead of vertically and the objects between which the angle is desired are brought into coincidence. If two or more observers take the angles between several objects around the ship, the angles obtained can be accurately plotted and a good fix obtained. Also after the ship is at anchor and is settled on its chain, the navigator can plot the ship's position accurately by using a round of sextant angles. Much practice is required before one can take angles with the sextant with any degree of accuracy. But the navigator should try to become proficient in this respect.

The stadimeter is a handy instrument for measuring distances in yards quickly and very accurately up to 2000 yards and with fair accuracy up to 10,000 yards. The use of the instrument requires that the height of the object from which the distance is being measured be known in yards. The stadimeter gives the navigator a small light instrument for measuring distances especially from other ships when approaching an anchorage. The instrument must be kept in adjustment. To adjust put the stadime-ter on infinity and on the lowest height. Bring the horizon line into a straight line by use of the adjusting screws on the instrument itself. A star may be used to adjust, and the star itself and its image brought into coincidence when the stadimeter read infinity and the lowest height.

A drafting machine consists of a protractor carried by a parallel motion linkage which is fastened to the upper left hand edge of the chart board. The linkage permits the movement of the protractor to any part of the chart without change of orientation and therefore the instrument affords great convenience in laying off a course or bearing from any chosen point and in the parallel transfer of a straight line to any desired position. Of the graduated rulers supplied, any two can be mounted on the protractor, one at right angles to the other if desired, to render convenient the plotting of lines of position. The graduated protractor-rim or compass-rose can be clamped as desired, and hence oriented to coincide with the north and south direction of the chart.

QUESTION #38. What are tides? Ocean Currents? How do they affect the navigator?

ANSWER #38. Tides are closely related to the passage of the moon over the meridian and are cuased by the attraction exerted by the moon and a little by the sun on the waters of the earth. Tides are a rise and fall of the water; tidal currents are the flowing of the water in or out of a place. The greatest height to which it falls is called low water; that moment at either high or low water when no vertical movement takes place is called "stnad" and the differences in height between low and high water is called "range" During ebb tide the water or tidal current is running out. During flood tide the tidal current is running in. The navigator must study the Tide Tables issued annually by the United States Coast and Geodetic Survey whenever making port. Around docks the currents will vary and unless the navigator knows their peculiarities much damage may be done to the ship trying to make such a dock. The navigator should keep a file of current conditions around docks which the ship may be required to make. Such information may best be obtained from the local pilots.

An ocean current is a progressive horizontal motion of the water occurring throughout a region of the ocean, as a result of which all bodies floating therein are carried with the stream. The set of the current is the direction toward which it flows. The dirft is the velocity with which it flows. The two main causes for currents are (1) the wind, and (2) the difference in the density and the temperature of the sea water in different areas. The first is the more important. The study of these currents is important to the navigator. When piloting they affect the course and distance the ship makes good and unless they are given due consider-ation may lead to disastrous results.

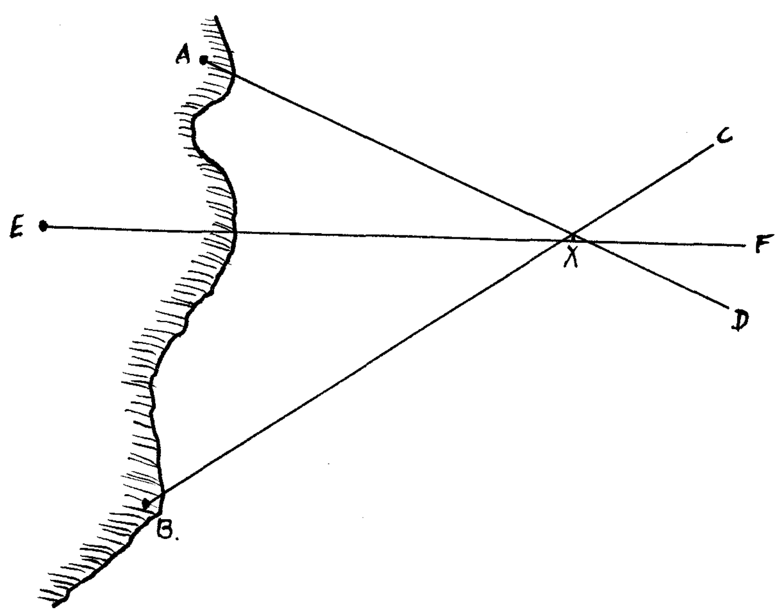
QUESTION #39. Discuss fog signals.

ANSWER #39. Regarding fog signals, the Light and Buoy lists show all stations or aids equipped to sound such signals. The navigator must remember that the direction and force of the wind and the presence of high land around the station affect the signals. Likewise there are certain dead areas around the stations in which the signals can not be heard. Men should be stationed around the ship clear of blower noises, etc., to listen for fog signals when they are expected to be heard. Too much attention cannot be paid to the importance of these valuable aids for navigation in thick weather

QUESTION #40. Show how to fix the position of the ship when there are well defined, known objects on the shore within sight.

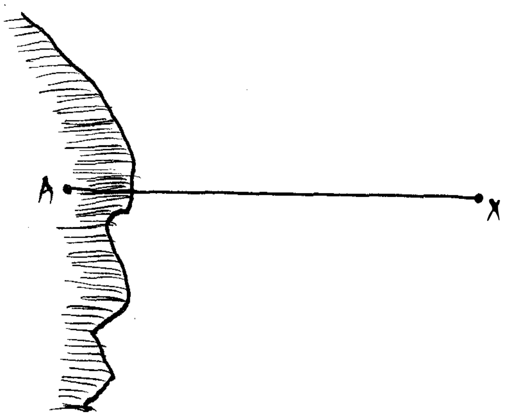
ANSWER #40. When the ship is in sight of objects ashore, whose positions are known accurately on the charts, the navigator may fix the position of the ship by any of the following methods: (a) Cross bearings of two or more known objects. (b) Bearings and distances of a known object. (c) Two bearings of a known object separated by an interval of time. (d) Sextant angles between three known objects.

Cross bearings of two or more known objects: In figure (attached) consider points A and B as two well defined objects on the chart. By use of the pelorus or azimuth circle, observe the bearings of each. Take one bearing as quickly as possible after the other then plot the bearings as shown by the lines BC and AD. Their intersection at X is the ship's position. To obtain the best results the bearings should differ as nearly as possible by 90°. The navigator must remember that the bearings taken must be corrected so that they will be ture bearings if the true compass rose of the chart is used (and it is best to use the true rose.) If a third well-defined object is in sight, a bearing of the may be taken at the same time and plotted with the other two. In the same figure E may be considered as that third object and the bearings EF plotted to check a fix. It may not be possible to get these three bearings to cross in a point. Their intersection may make a small triangle. If they do the fix is in the center of the triangle. When cruising on soundings the position X may be verified by taking a sounding at the same instant the bearings are taken. Objects whose bearings differ by only 30° or more than 150° do not give accurate fixes. Small errors in bearings give large errors in the fix because the lines are nearly parallel.



QUESTION #41. Show how to fix the ship's position by taking the bearings and range of a known object ashore.

ANSWER #41. In figure 2 (attached) A is the prominent mare on the chart. On large ships with accurate range finders, the distance from the ship to the object may be measured at the same instant as the bearing is taken. By plotting the bearing and measuring the distance along that line, the position X can be determined. Also if the height of the object is known the distance may be measured by the sextant as explained. Table 33 in H.O. publication No.9, American Practical Navigator (or Bowditch as it is commonly called) for 1925, gives distances up to 5 miles corresponding to various heights with their angles. Again the position X may be verified by a sounding.



QUESTION #42. Show how to fix the ship's position by taking two bearings of an object with an interval of time between them.

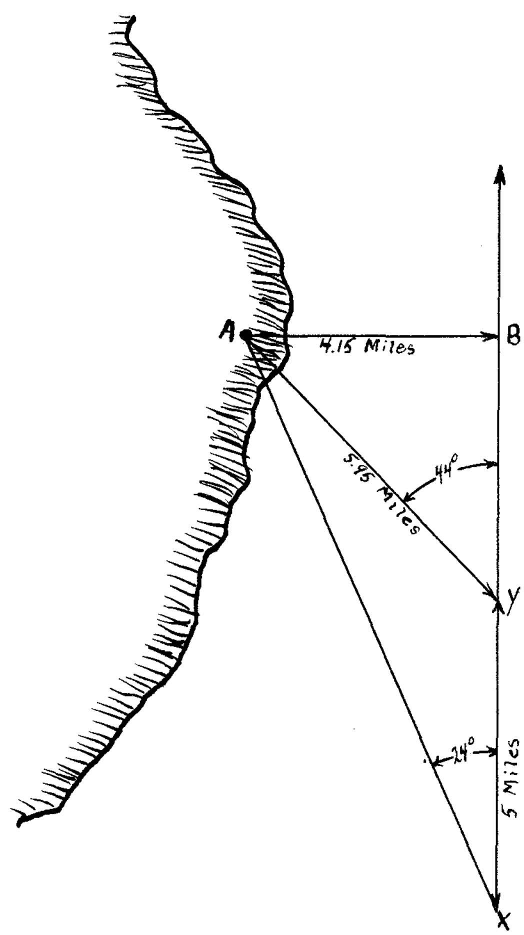
ANSWER # 42. Consider the ship steaming along the line XB in Figure 3 as shown by the arrow only one well defined object A is in sight. The navigator takes a careful bearing of A when the ship is at X and at the same time has the quartermaster read the patent log (if one is in use and is accurate) and note the exact time. The ship steams along and care is taken to hold it to an accurate cours at a constant speed. When the ship reaches Y, the navigator takes the second bearing and again the log is read and the time noted. By referring to Table 5B in Bowditch the distance at which the vessel will pass the object A abeam AB and the distance from the ship to the object at the time of the second bearing AY can be found as follows: The differnece between the readings of the log when the two bearings are taken, equals the distance run. Likewise from the interval of time elapsing between the two bearings, and the speed in knots, the distance run between the bearings can be found. Knowing the distance run, Table 5B gives a multiplier to be used with it to get the desired results. For example: Ship making 15 knots per hour; bearing of A found to be 24° on bow at 10:20AM at 10:40AM the bearin is found to be 44° on bow. (1) How far will ship pass A abeam? (2) How far is A away at time of second bearin From 10:20 to 10:40 the ship steams 20 minutes of one-third hour at 15 knots or 5 miles (sea) From Table 5B the multiplier to be used to find (1)is o.83 and to find (2) is 1.19. Therefore the ship will pass 5 x 0.83, or 4.15 miles abeam and is 5 x 1.19 or 5.95 miles away when the second bearing is taken. The multiplier in the first column of Table 5B is used to find the distance to the object at the time of the second bearing. The one in the second column to find the distance at which the ship will pass the object abeam. Certain special cases of this problem are very easy to remember and apply. The most common cases are listed herewith:

(1) If the second angle on the bow is twice as large as the first angle on the bow the distance run between the bearings will equal the distance from the object at the time of the second bearing.

(2) If the first bearing is 22½° on the bow, and the second is 45° on the bow, then seven-tenths of the distance run between them will equal the distance the vessel will pass abeam.

(3) If the first bearing is 22½° on the bow and the second is 26½° on the bow, then seven-thirds of the distance run between them will equal the distance the vessel will pass abeam.

(4) If the first bearing is 26½° forward of the beam and the second 26½° abaft the beam the distance run between the bearings equals the distance at which the ship passed the object abeam.



QUESTION #43. What are "bow and beam" bearings?

ANSWER #43. This question answered under question #42.

QUESTION #44. What is a danger bearing?

ANSWER #44. The shore line has a shoal extending out from it. The navigator desires to keep clear. The navigator draws a line from some prominent landmark, so that it clears the shoal at all points and notes the compass bearing of that line. The navigator keeps taking bearings of the landmark and keeps that bearing to the left of the bearing of the line at all times. Certain lights show white over safe waters and red over dangerous areas. The red sectors are shown on the chart and the navigator knows that so long as he keeps in the white sector of the light he is safe. Danger bearings should always be used.

QUESTION #45. Discuss the use of soundings to fix the ships position.

ANSWER #45. If the navigator can determine the amount of water under the ship by the use of a sounding machine, he can locate the ship by comparing the sounding received with the depth of water shown on the chart. It will be found however that even on large scale charts one sounding will not locate the ship accurately enough for safty and comfort. When cruising along a coast line in a fog or thick weather the navigator should take soundings at regular intervals or should run a line of soundings as it is commonly called.

QUESTION #46. What are the various ways in which soundings can be obtained?

ANSWER #46. There are three methods of obtaining soundings: By the use of a sounding machine, a sonic depth finder or by use of the hand lead. The sounding machine reels out wire to which is attached a lead with a cavity. The lead is armed to bring up a sample of the bottom. This enables the navigator to compare the sample with the character of the bottom as shown on the chart. Attached to the wire is the cylindrical case for holding the depth registering device. It works on the principle of different pressures at different depths. The scale on the device measures the part of the glass which is discolored. The sonic depth finder is much more adapted taking deep sea bearings. A sound signal is sent to the bottom which is reflected back to the listener. Knowing the speed of sound in water it is very easy to compute the distance to the bottom. There are two methods of using the sonic depth finder: One is the angle of reflection method for depths up to 40 fathoms and the other the echo method for depths over 20 fathoms. The hand lead is used for very shallow waters and can be used when the ship is maneuvering at a slow speed. The sonic depth finder can be used at any speed and bearings may be taken every 10 seconds. Using the sounding machine it is necessary to stop the ship.

QUESTION #47. In what way are the following devices of assistance to the navigator?

(a) Submarine Bell?
(b) Radio Compass.
(c) Radio Beacon.
(d) Sonic depth finder.
(e) Ordinary sounding machine.

ANSWER #47. The Light lists show stations equipped with submarine signalling devices and give characteristics of the signals at each station. If the navigator is listening for a signal, he turns the switch so as to connect either the port or starboard microphone and listen in that receiver. He then switches back and forth, in orde to determine in which receiver the signal is strongest. The bow on which the signal is heard loudest indicates the approximate bearing of the transmitting station. If the ship is turn until the signal is of equal intensity on each bow the ship is then pointed at the sending station. The submarine bell is of great assistance to the navigator in ascertaining his position with respect to a known station.

The greatest aids to the navigator when piloting or coasting in thick weather are radio compass bearings. Bearings are obtained by using a procedure which all radio operators understand. The navigator must know , however, the location of radiocompass stations and their positions relative to the ship. Bearings can be obtained with ease up to 150 miles. Over 50 miles from the station, however, bearings plotted on a Mercator chart have a certain distortion, since the radio compass station gives true bearings. Radio compass bearings are invaluable aids and the navigator should use them constantly, even in clear weather.

In certain important localities stations are equipped to send out distinctive radio signals broadcasting them at certain intervals. Ships equipped with radio-compasses or direction finders pick up these signals and get the bearing of the sending station by such compasses. They are then able to steam toward the station to make a landfall. These radio signals are usually sent out only in fogs or thick weather.

The sonic depth finder is used for taking soundings of the ocean's bottom when the ship is steaming at any speed. They give a good picture of the ships bottom and are a great help to the navigator when the weather is thick and foggy.

The Ordinary sounding machine is used where the weather is not too rough to stop the ship, as the use of the ordinary sounding machine makes it imperative that the ship be stopped. The decided advantage of the ordinary sounding machine is that it brings up a sample of the the bottom of the ocean at that spot and the navigator may compare the sample brought up with the bottom as listed on the chart and after several such samples can check on the accuracfy of the soundings.

QUESTION #48. Under what circumstances and why must radio compass bearings be corrected for the use of the navigator?

ANSWER #48. When a single radiocompass bearing is received there is a possibility of its being in error by approximately 180°. The operator can not always determine on which side of the station the ship really is. If a bearing is received which is the approximate reciprocal of the correct bearing, the navigator should never attempt to correct this bearing by applying a 180° correction to it. Such a correction does not include the correction due to the deviation at the compass station itself. An error of as much as 30° may be introduced by applying this arbitrary correction. It must never be done. The bearing must be referred back to the radio-compass station for correction according to the particular deviation at that bearing, before the navigator can use the bearing.

QUESTION #49. Describe how to lay off a course and speed on a chart and how to pick off a position (latitude and longitude)

ANSWER #49. To lay off a course on a chart, lay down a parallel ruler so that its edge joins the point of departure and point of destination. Move the parallel ruler parallel to itself until the same edge passes through the nearest "compass rose" The degree mark, where the edge passing through the center of the rose cuts the circumference, represents the course. Likewise to put a certain course on the chart from a given point, place the edge of the parallel ruler so as to pass through the center of the compass rose and the degree mark on the circumference representing the desired course. Then move the ruler parallel to itself until the same edge passes through the given point and draw a light line on the chart in the desired direction. The relation between true and compass courses must constantly be remembered. Likewise the fact that the variation changes in different areas must be considered. To lay off the speed on the course, with a pair of dividers, pick off as many minutes of latitude off the latitude scale as the speed in knots per hour, remembering to use the part of the scale which is nearly the center of the course traveled. Then point off on the course as many lengths of the divider as there were hours run.

To pick off a position, look up and down the scale on the right or left hand side of the chart (latitude scale until you find the desired latitude. Draw a horizontal line out from this reading. Then look to the left and right of the bottom or the top scale (longitude scale) until you find the desired longitude. Draw a line vertically until it intersects the horizontal line drawn before. The point of intersection will be the position.