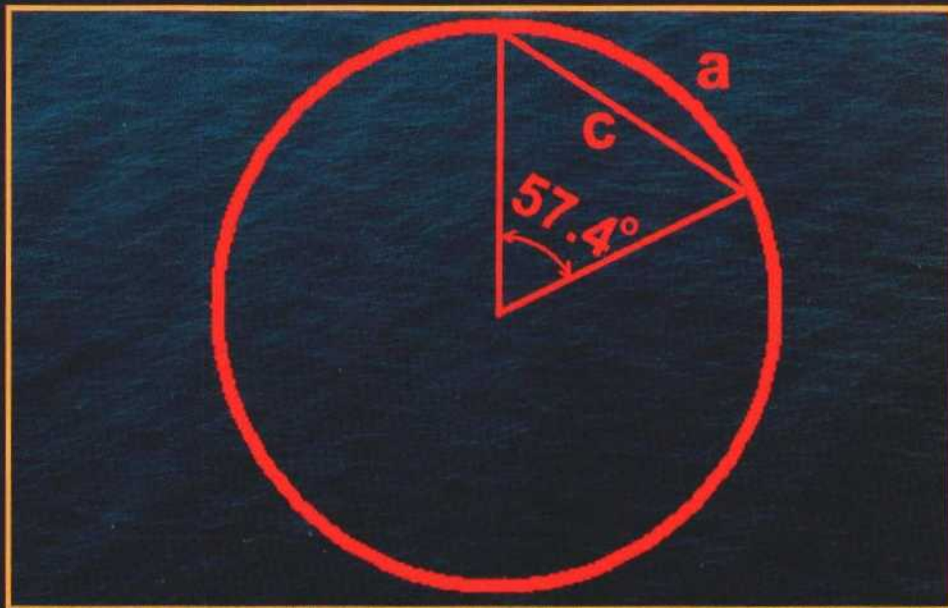
25th Anniversary of...

Editor's Note: This article was originally published in the March 1979 issue of Surface Warfare magazine, and reprinted 8 years later. The author, LT John V. Hall of the USS **Power** *(DD 839) retired from the naval service in 1979. We receive numerous requests for copies, so in honor of CAPT Hall's article, we have added information to the original article using contributions from Marine Safety International. As more Sailors attain qualification as OOD, or stand watch as Junior Officer of the Deck or Junior Officer of the Watch, we hope to receive many more innovative approaches to shiphandling for publishing!*



▲ One radian is approximately 60 degrees. We use the radian rule for small angles (30 degrees or less) to approximate the length of the short side of a triangle by assuming the ratio is 1 to 60 compared to the long side.

As the techniques and machines designed to aid in all phases of operations become more numerous and sophisticated, it seems a pleasure to realize that in one vital area no substitute has been found, or is likely to be for the exercise of good human judgment and thought, aided by rather simple equipment of long standing.

The conning officer does of course have numerous aids to help perform even the most elementary maneuvers. CIC, radar, and the maneuvering board are close at hand. Information concerning contacts is clearly displayed. Everything on the bridge seems to be calm, in order, ready. Probably it is. But somehow, something can come up fast enough and unexpectedly enough so that an almost instantaneous decision will have to be made without much outside help.

Even if help and recommendations are quickly forthcoming, there is still the question, is this correct? Is it the safest, quickest and best way? The responsibility for making this determination does not leave the bridge; it is there to stay.

The conning officer then has an obligation to use every means available to quickly and accurately make this determination. The OOD is required to study pertinent tactical doctrine, the maneuvering characteristics of his own ship and other types, and maneuvering board. He is required to give and receive instruction so that his decision will always be acceptable. There is however, a faculty which an OOD can develop and use effectively with just a little analysis and practice, but which few seem to consciously use. It is no more than mental arithmetic, based on a variety of simple rules.

When the OOD uses "thumb rules" in maneuvering, he is merely applying a little pre-cooked math to a specific situation. When he exercises "seaman's eye", he is also making mathematical calculations, but on a level below (or above) the level of conscious figuring. Let's look for a minute at one simple device: radian measure.

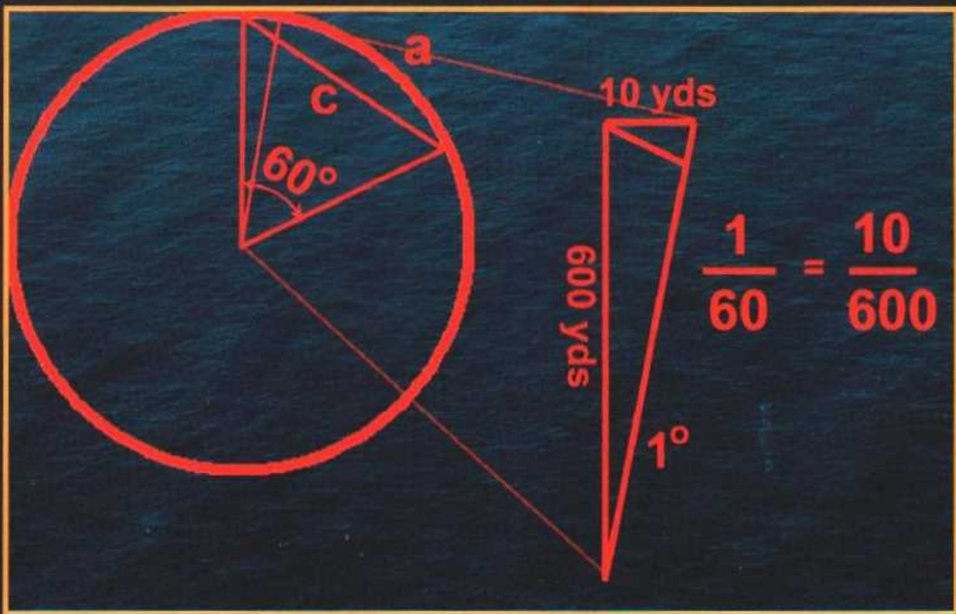
Most OOD's have run across the radian at one time or another in elementary math courses. Few appreciate it properly.

What is a Radian?

A radian is defined as the angle which subtends an arc of a circle

Quick Math for OOD's

By LT John V. Hall, USN and Marine Safety International



▲ Applying the radian rule here, 1 degree to 60 degrees is the same ratio as the side opposite of one degree to the adjacent side – 10 yards to 600 yards.

where the length of the arc equals the radius. In the drawing, arc a, radius r and chord c are shown. When a = r the angle shown is one "radian" or 57.4 degrees.

If we round 57.4 to 60, we can say that the length of the arc created an angle of 60 degrees is going to be approximately equal to the radius. Consequently the length of the arc subtended by an angle of 1 degree is going to be approximately 1/60 of the radius, 2 degrees, 2/60 of the radius, 10 degrees, 1/6 of the radius, and so forth. For small angles (30 degrees or less), the arc (a) and chord (c) are approximately equal.

Simply put: for every angle of 1 degree, the ratio f the long side of a triangle to the short side is 1 to 60. So for the triangle shown, if the long side is 600 yards, then the short side is 10 yards.

For instance:

You see a fishing boat about two miles ahead, 3 degrees on your starboard bow. He seems to be DIW. How close do you come if you hold your course?

True this is an instant's work on a maneuvering board. But why not convert that 3 degrees to 1/20 of a radian (3 degrees / 60 degrees), and then take 1/20 of the range, thus

▲ While bearing drift, the constant change of an object's bearing from the ship, will help determine if a danger of collision exists, the actual range of the closest point of approach (CPA) can be found using the radian rule.

▲ The Amphibious Command Ship (right) has an overall length of approximately 600ft. A 1 degree starboard course change swings the stern toward the guide ship by at least 10 feet, the decrease in pressure due to water moving faster through a narrower opening could make steering more difficult.

getting your 200 yard CPA? Too close? Five hundred yards would be better. Well, 500 is 1/8 of 4000, and 1/8 of a radian is what? Between 7 and 8 degrees. To clear him by 500 yards, starting now, you should steer about 8 degrees off his bearing so you come left 5 degrees.

Another application of the radian rule:

While alongside during an unrep, one of our primary concerns is keeping a safe distance from the delivery ship. Since we routinely steer courses to the left and right of replenishment course while adjusting position, it would be useful to know how this affects the position of our stern. There are a lot of variables at work during an unrep but figuring out the lateral movement of the stern (at least theoretically) for a heading change is relatively easy to do. For simplicity, assume our ship is 600 feet long. If we change heading 1 degree, and if we assume the ship pivots at the bow (a "worst case" scenario), we apply the radian rule ratio of 1/60 and conclude that the stern moves left 10 feet. Since we know that the ship will pivot somewhere aft of the bow, the 10 foot figure represents the most the stern will move toward the delivery ship for every one degree of heading change.

Yet another application…

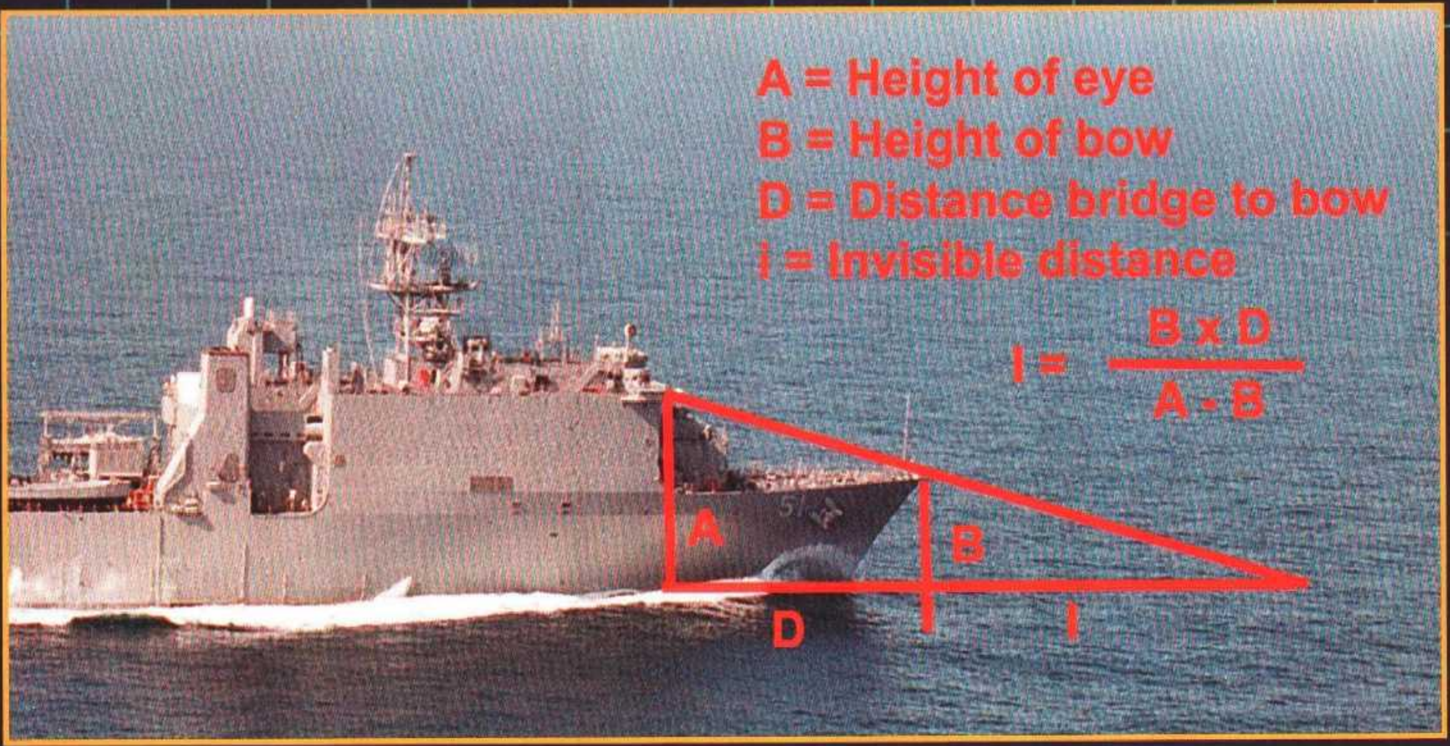
Most unreps are conducted at a speed of 13 knots. When the receiving ship steers a heading to the right or left of Romeo Corpen she should either open or close depending on what side of the delivery ship she is on. It is useful to know what the rate of lateral opening or closing is for every degree of heading difference. In the diagram to the right, the two ship's vectors are shown with a heading difference of one degree. If we take 1/60 of 13 knots (which happens to be 1300 feet per minute) we get 21.6 feet per minute (fpm), which we round off to 20 fpm. Thus, in the absence of other forces, for every one degree of heading difference from Romeo Corpen we open (or close) at the rate of about 20 feet per minute.

Getting out of close quarters — the "five degree" maneuver:

If, by some circumstance, you find yourself dangerously close to the oiler, say 60 or 80 feet, you have to open the distance quickly because interactive forces are increasing exponentially and you are running out of time. You initiate emergency breakaway; but you can't floor the accelerator until the rigs are clear, and the increase in speed of water passing over the hull may cause the water pressure between ships decrease further, increasing chances for collision. You are so close that you're concerned that if you come right, your stern may hit the delivery ship. Nevertheless, that's what you have to do and what's more, you have to make a decisive course change.

Assume you are to starboard of the oiler. As we learned above, for

▲ Applying the radian rule to speed vectors, we see a 1 degree course change at 13 knots during calm weather conditions causes the ship to open at 20 feet per minute.



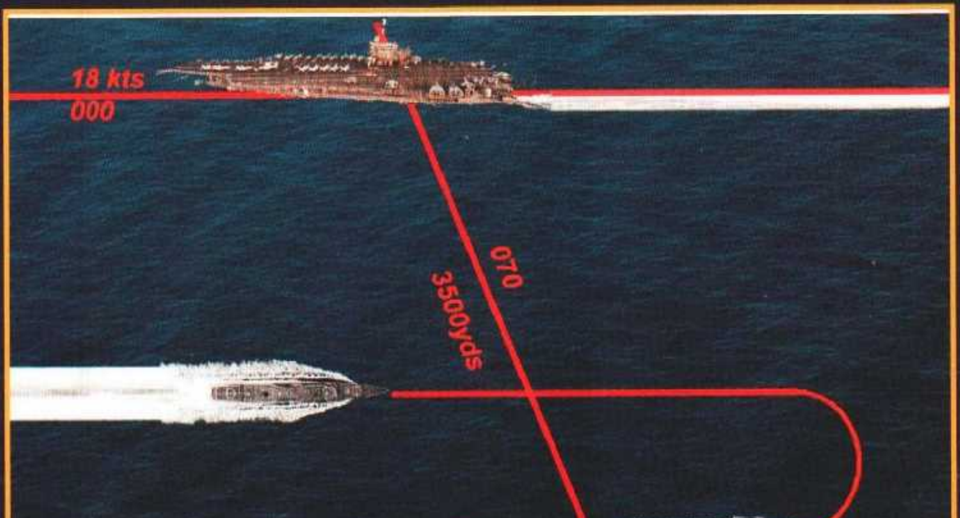
▲ The blind area created by a particularly rakish bow or low superstructure can be a dangerous region. Small boats should never drive under the bow.

every degree of heading change to the right the stern move left and will close the oiler by as much as 10 feet (for a 600 foot long ship). At the same time, however, each degree of heading change to the right adds about 20 feet per minute to your opening vector. Thus, if you make a course change to the right of five degrees, your stern will close by at most 50 feet. At the same time you will achieve an opening rate of 100 feet per minute or more. In fact, as the ship comes right even though the stern rotates toward the delivery ship, it closes by much less than 50 feet because the opening vector takes effect and the ship tracks to the right.

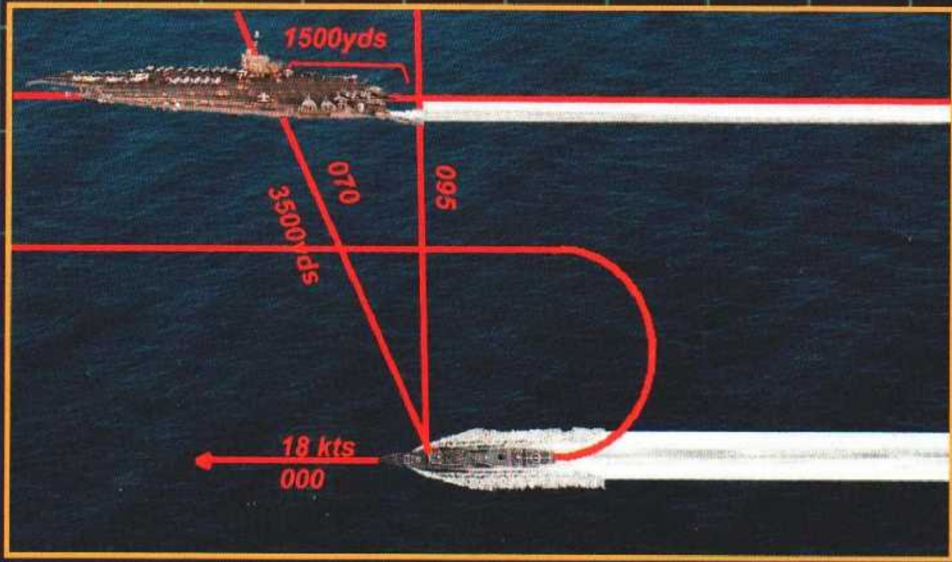
It is recommended that this "five degree" maneuver be executed by giving a course order (i.e. "Helm, come right smartly to XXX.") vice a rudder order and that the helmsman be a qualified master helmsman who has been briefed to anticipate such an order in the event of an emergency breakaway. You may choose to use rudder orders, but the helmsman may be carrying significant amounts of rudder already to hold the ordered course and will know what's needed to execute a smart course change. The real challenge in this maneuver may be returning to base course before you open up too far.

The Three Minute and One Minute Rules

Experienced OODs are well versed in the three minute rule which states that the distance in yards traveled in 3 minutes is equal to the speed in knots multiplied by



▲ At a signal's execution, a ship must expeditiously maneuver to station while minding safety of navigation.



▲ In the 2.5 minutes it takes to turn at 20 knots, the guide will travel 1500 yards. The ratio of 1500 yards to the range at station is slightly less than half a radian, approximately 25 degrees. Turn when the guide bears 095, 25 degrees greater than guide's bearing when at station.

100. Thus a ship going 10 knots travels 1000 yards in 3 minutes. For slow speeds it may sometimes be useful to use the one minute rule which is essentially the three minute rule divided by three. The one minute rule says that the distance traveled in feet in one minute is equal to the speed in knots multiplied by 100. Thus a ship approaching a berth at 2 knots will travel 200 feet in one minute.

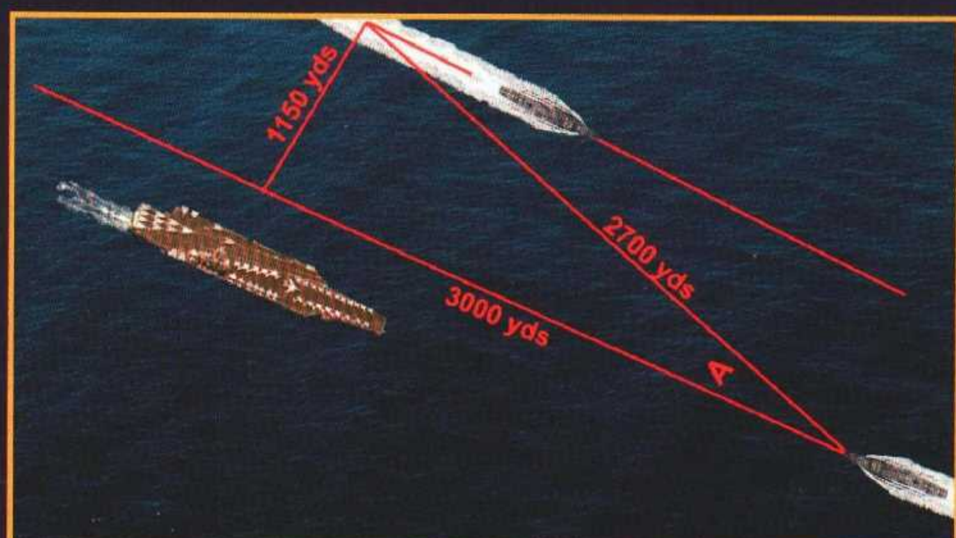
The Invisible Distance Formula

The Invisible distance formula is not quick math. It has to be calculated in advance but once calculated it provides a useful tool for close quarters situations. A good example of its use is the situation where you are entering a berth and need to estimate the distance ahead to a fixed object such as the quay wall. From the bridge, your line of sight over the bullnose will intersect the surface of the water at some distance ahead of the bow which, given your height of eye and the typical draft and trim of the vessel will be a fixed distance. Typically for CGs and DDGs this distance is about 80 or 90 yards. However, using the drawing and formula below you can calculate what it will be for your particular ship. You will find that differences in height of eye and small changes in ship's draft will not affect the result very much.

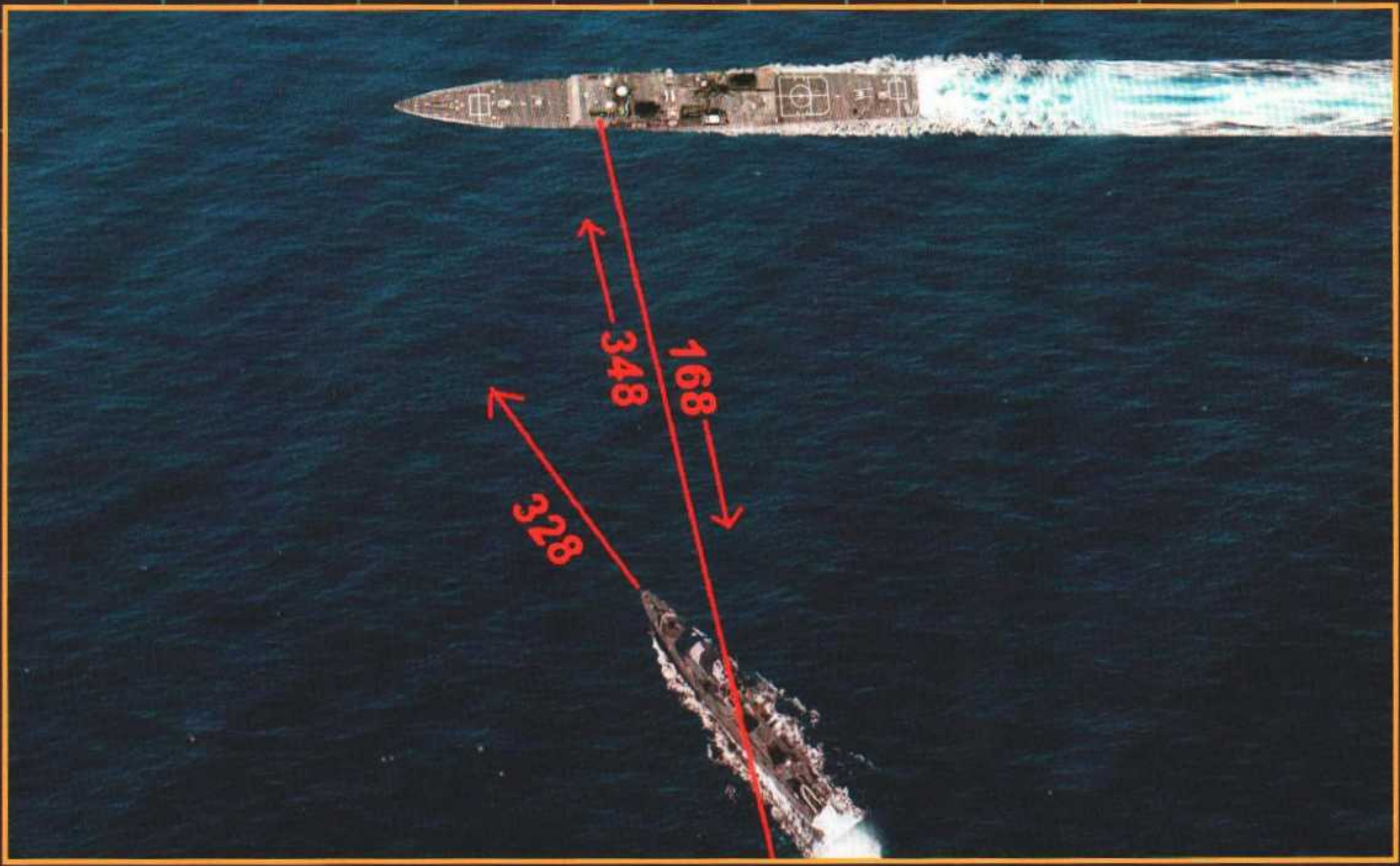
One of the things an OOD is expected to know is, of course, the maneuvering characteristics, or "tactical curves" of his ship. Usually this will comprise a volume of figures and graphs, which can scarcely be memorized. However, it is imperative for the OOD to have a rather accurate knowledge of advance, transfer, turning diameter and turning rates for various speeds and rudder angles. It is not too much to memorize figures for, say, ten, fifteen, twenty, and twenty-five knots, the same rudder angles, and 180° of turn. In any event, the data should be most readily accessible, preferably in a handy tabulated form.

Now suppose that you are a considerable distance ahead of your guide, and you are told to take station much closer, dead ahead. You decide to turn and head back on the reciprocal course, almost "down the throat". He's making 20 knots, you are at 25, and suddenly there you are with a closing range of nearly 45 knots and a decision to make. It is well to come prepared.

Your station is 1000 yards dead ahead of the guide, and you have decided to turn back to base course at 25 knots with 15 degrees rudder, slowing to 20 as you begin to steady up on base course. Now you absolutely must know how long that turn is going to take.



▲ In the 2.5 minutes it takes to turn at 20 knots, the guide will travel 1500 yards. The ratio of 1500 yards to the range at station is slightly less than half a radian, approximately 25 degrees. Turn when the guide bears 095, 25 degrees greater than guide's bearing when at station.



Target angle offers useful information to quickly plan or visually confirm the course of a contact calculated by CIC.

For safety's sake you are going to assume it takes three minutes. In three minutes the guide will approach you by a matter of 2000 yards, due to his own motion. Therefore, when his range is 3000 yards you will turn, and when you have completed your turn and slowed to 20 knots, you will be just about 1000 yards ahead of him, actually a trifle more. However, if from necessity or choice you are going to do it as described here, there is no other way than to make these calculations. CIC can do no more and you may be lucky if they react quickly enough to do as much. A maneuvering board is no help. It will have to be done in your head.

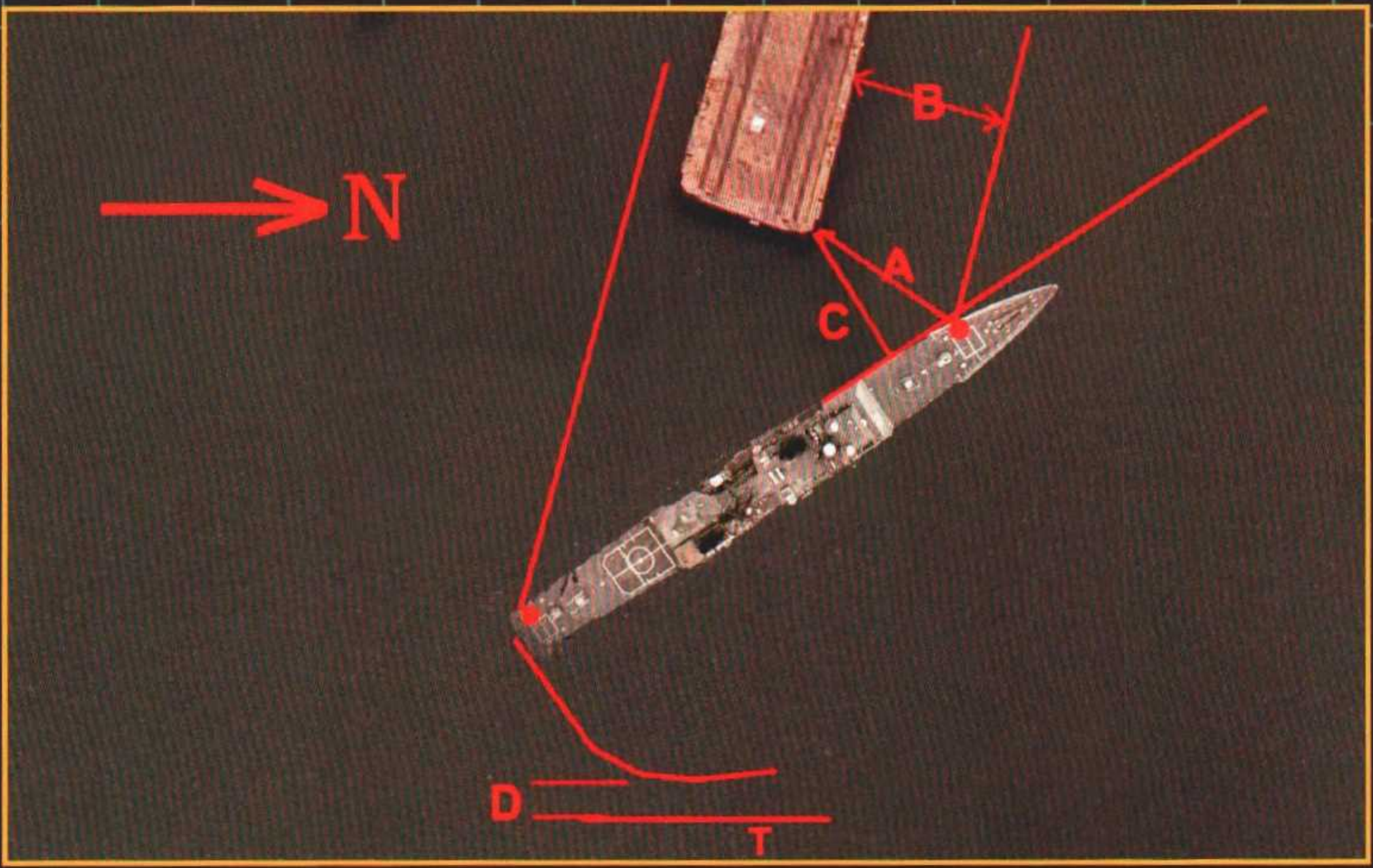
Here you are coming into what might be screen station, 3500 yards from the guide and somewhat abaft of his beam. His course is 000°, speed 18, and when on station he will bear 070°. You are coming down a more or less reciprocal course along the track shown at 20 knots.

You chose your course, by eye or by maneuvering, so as to be displaced towards the guide's track by the diameter of your turning circle. Now as you close him, you are again wondering where to start your turn.

Begin by assuming that your turn will take place at a point. The point chosen is the one you reach on completion of your turn. when there, you hope to be on station. This assumption will introduce error, but not much in a situation similar to this example. This turn is going to take (you know or have looked it up) 2 minutes at 20 knots, with standard rudder. Again you are going to slow to 15 knots towards the end of the turn.

While you spend 2 minutes turning, the guide will go how far along his track? About 1500 yards, by the three minute rule. Those 1500 yards are less than half of your 3500 yards final range. The angle A above is therefore a little less than half a radian, say 25 degrees. Therefore when the guide bears 005, you will begin your turn.

Now when you look at it objectively, what could be simpler to calculate? All you used was the knowledge you had anyway, plus the radian rule. You make no attempt to be absolutely precise. You used several approximations, for simplicity's sake. Probably you turned a little late, and corrected for that immediately on coming out of your turn. What gave your mental calculations their value was the fact that you knew you would come out quite close to station.



▲ To the observer on the bow, the north face of Pier 1 is "OPEN", A is the "DISTANCE TO" Pier 1, B is the offset of the bow "FROM" the face of Pier 1, and C is the offset of the port side "TO" the end of Pier 1. To the observer on the stern, the south face of Pier 1 is "OPEN", the north face of Pier 1 is "CLOSED", the stern "HAS SWING CLEARANCE" on buoy T, or the swing clearance on buoy T is distance D.

At the moment you began your turn, the situation looked like this:

You turned with the guide at a range of 3000 yards. With your turning diameter of 1150 yards, the angle A was a little over one-third of a radian, say 25 degrees. The distance from C to P was therefore only 2700 yards. If your turn had, in fact taken 3 minutes, as you assumed, you would have ended up only 700 yards ahead, which could be cutting it rather fine, to say nothing of putting you 300 yards behind station. That extra half minute you allowed for the turn served to compensate for 300 yards, inasmuch as half a minute represented very close to 300 yards in the advance of the guide along his track.

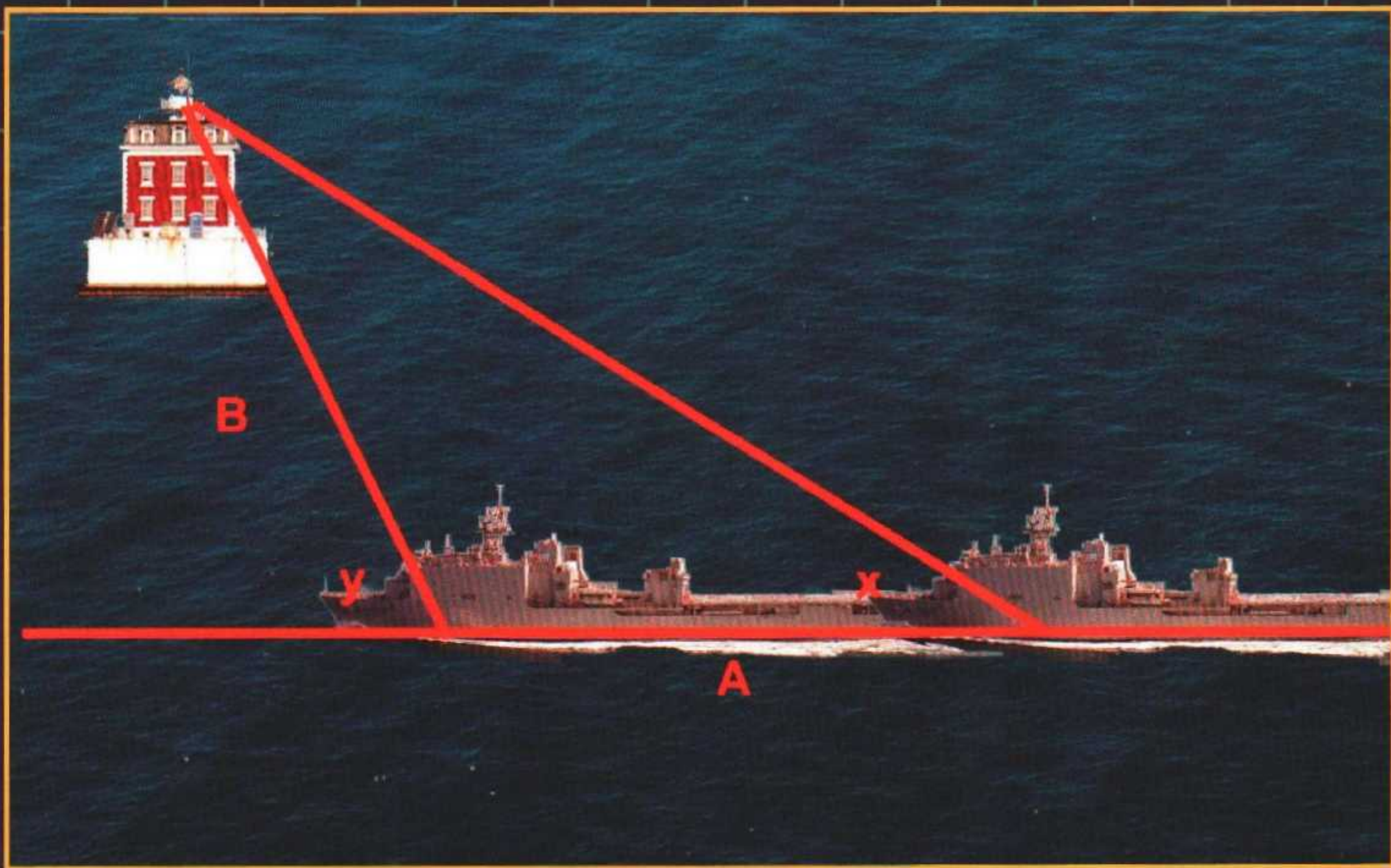
How do most OOD's figure reciprocal bearings? A quick glance at the maneuvering board is no doubt easiest and surest. But if you want to do it in your head, do you try to add or subtract 180 degrees? This can become awkward, and can lead to errors. Why not add 200° and then subtract 20, or conversely subtract 200 and add 20? This is of course extremely simple, but have all OOD's thought of it?

Few OOD's realize target angles, reciprocal bearings and angle-on-the bow can be useful tools to determine a contact's course.

The contact bears 168°. The reciprocal is 348°, the contact is 20 degrees on the starboard bow. Contact course 348° minus 20 equals 328°. The solution is found in an instant, and if your estimate was good, will be better than CIC's, which may not be available anyway for two or three minutes.

Visualizing relationships is a large part of using "quick math" to help you determine contact course, CPA, and other information, but it can also help you communicate better.

Conning officers often rely on reports from the foc'sle and fantail to judge the ships position and movement. This is only useful if everyone is speaking the same language. The drawing below suggests several terms and definitions that might prove useful in communicating between the bridge and various lookouts.



▲ Running fixes can be especially useful when visual bearings are only available on one side of the ship.

Doubling the Angle on the Bow (A Classic DR tool)

Another application of basic trigonometry can be useful in obtaining an estimated position from a single landmark. Shoot the bearing to a fixed object and record the difference between your heading and the bearing (angle on the bow). Maintain course and continue to shoot bearings to the object until the angle on the bow is twice what it was at the first bearing. At that point, your distance from the fixed object is equal to the distance traveled between the two bearings. The bearing and distance thus obtained can be plotted as an estimated position.

It would be impossible to exhaust the situations in which an OOD should be able to find fast and reasonably accurate mental solutions to maneuvering problems. The variety of techniques, tricks, and thumb rules is also endless. I believe, however, that it is appropriate to stress that this type of thinking, and mental preparation, should be just one typical part of an OOD's continuous and analytical effort to qualify himself to meet any situation which may arise.

The radian rule and the three minute rule are excellent aids to an OOD in the execution of his conning responsibilities on the bridge. Their use is for assisting in making rapid and accurate maneuvering decisions. The following test represents applications of mathematics that OOD's should be able to do (sans caluculators).

(The test is not included here – go online to www.navsea.navy.mil/swmagazine and download the test and 50 variations!)