STUDY AID

Coastal Navigation & Piloting

Aids, fixes, set and drift,
tides and currents

Capt. Georgia Hilton

The four-block worksheet — the same layout every time

1. DESIRED STATION — the offsets

- Station number and name
- Time difference, high and low
- Height difference or ratio

2. REFERENCE STATION

- Which station it refers to
- Its times of high and low
- Its heights

3. CALCULATIONS

- Apply the offsets to get YOUR station
- Duration of rise or fall
- Range of tide
- Time from the nearer high or low

4. ANSWER THE QUESTION

- Table 3 for the correction
- Apply it to the nearer high or low
- Check the answer is between them

The companion to *Terrestrial Navigation*, and the half of the module that happens within sight of land — where the mistakes are expensive. Everything here is worked the way you already teach it: the four-block worksheet on this page is your layout, not a competing one, and the tide and current examples are your own demonstration problems with the arithmetic checked from first principles.

The four things that decide a tide or current problem.

1. The tables are printed in **LOCAL STANDARD TIME**. A question in daylight time must be put back an hour *first*.

2. Tide height follows a **COSINE** rule. Current velocity follows a **SINE** rule. They are not the same curve.

3. Tides are corrected from the nearer **high or low**. Currents are worked from **slack**.

4. Apply the offsets to get *your* station before you do anything else. Every error that survives to the end started by skipping that.

SECTION 1

The chart

What you are actually reading, and the datum question that decides whether you touch.

A chart is a projection, a datum, a scale and a date, and all four matter. The **projection** is almost always Mercator, so a straight line is a rhumb line and you can lift a distance off the latitude scale at the side — **never** off the longitude scale along the top and bottom, because a minute of longitude is not a mile except at the equator.

Two datums, and they are not the same datum.

The horizontal datum fixes where a position *is*. Modern charts are on WGS 84 or NAD 83, which agree closely enough to ignore; an old chart on a local datum can put you hundreds of metres out, and the note in the chart's title block tells you.

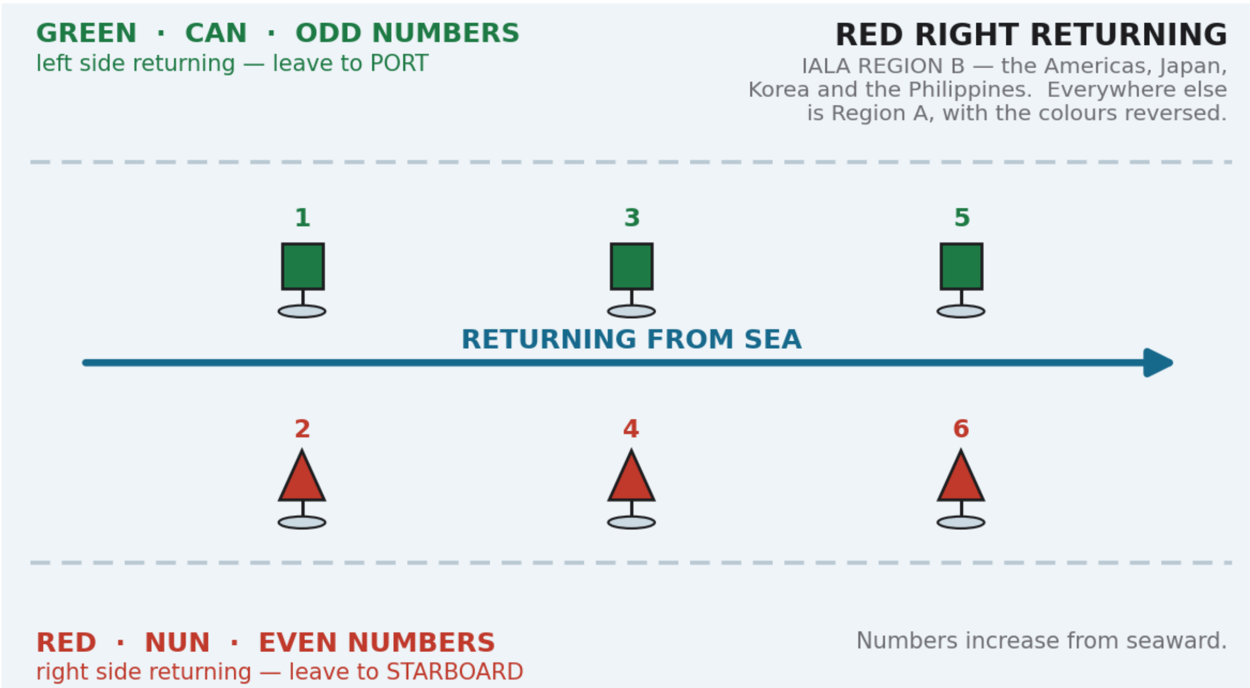
The vertical datum fixes what the soundings *mean*. On US charts it is **mean lower low water**. On British Admiralty and most IHO charts it is **lowest astronomical tide**, which is a lower and therefore more conservative surface. Heights of land features and bridge clearances are referenced to a *different* datum again — usually mean high water — so do not assume one number tells you about the other.

The **scale** decides how much detail exists at all. A large-scale chart — a small area, a big number on the ground per inch of paper — is the one you must use in confined water, and using a small-scale chart for pilotage is a finding in most groundings. **Corrections** are the rest of it: a chart is only as good as the last Notice to Mariners applied to it, and the correction record is in the bottom left corner.

SECTION 2

Aids to navigation

The lateral system, and the fact that half the world does it backwards.



The United States is IALA Region B. Everywhere else in this diagram the red and green swap sides.

The whole lateral system hangs on one idea: **which way is** ‘**returning from sea**’. In the United States that is generally northward along the east coast, northward and westward on the Gulf, and northward along the west coast — and where it is ambiguous the chart tells you.

Mark	What it looks like	What it means
Lateral, port hand	Green, can (cylindrical), **odd** numbers, green light	Leave it to **port** when returning from sea
Lateral, starboard hand	Red, nun (conical), **even** numbers, red light	Leave it to **starboard** when returning from sea
Preferred channel	Red and green horizontal bands. The **top** band gives the preferred channel	Red on top — preferred channel to starboard, so treat it as a red mark
Safe water	Red and white vertical stripes, spherical or with a red spherical topmark, Morse A light	Mid-channel or a landfall mark. Pass on either side
Isolated danger	Black with a red band, two black spheres, group flashing (2)	A danger with navigable water all round it
Special mark	Yellow, yellow light	Anchorages, spoil grounds, cables. Not a navigational hazard as such
Range	Two marks of different heights, the rear one higher	In line, they give a precise course — and a free compass check

Light characteristics are a shorthand: **Fl** flashing, **Q** quick, **Oc** occulting (light longer than dark), **Iso** equal light and dark, **Mo(A)** Morse A. A number in brackets is the group. The figure after it is the period in seconds — the whole cycle, which is what you time with a stopwatch to identify it.

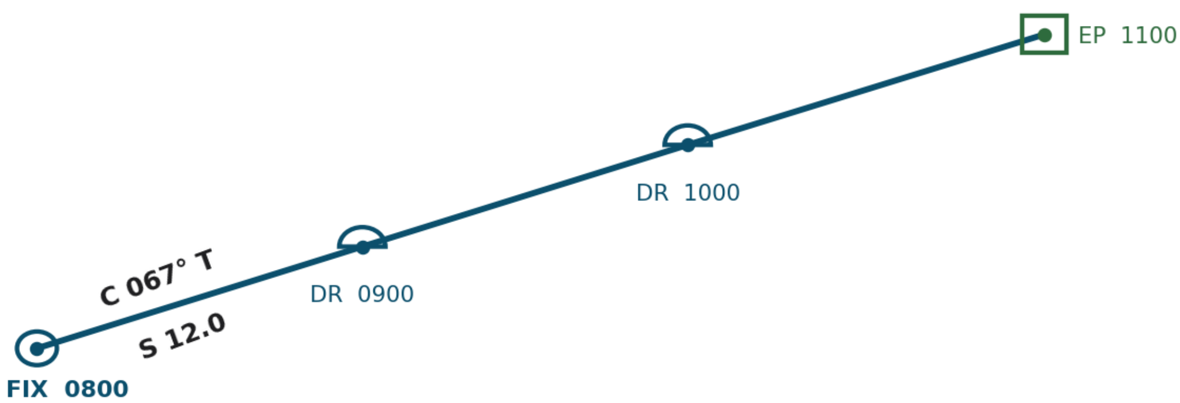
SECTION 3

Dead reckoning

Course and speed only. The moment you add anything else it stops being a DR.

LABELLING
Course ABOVE the line, three figures TRUE.
Speed BELOW the line.
Times in four figures, no colon.

THE THREE SYMBOLS
circle = FIX, an observed position
semicircle = DR, course and speed only
square = EP, a DR with set and drift in it



A DR position is advanced ONLY for course and speed. Put a current in it and it stops being a DR.

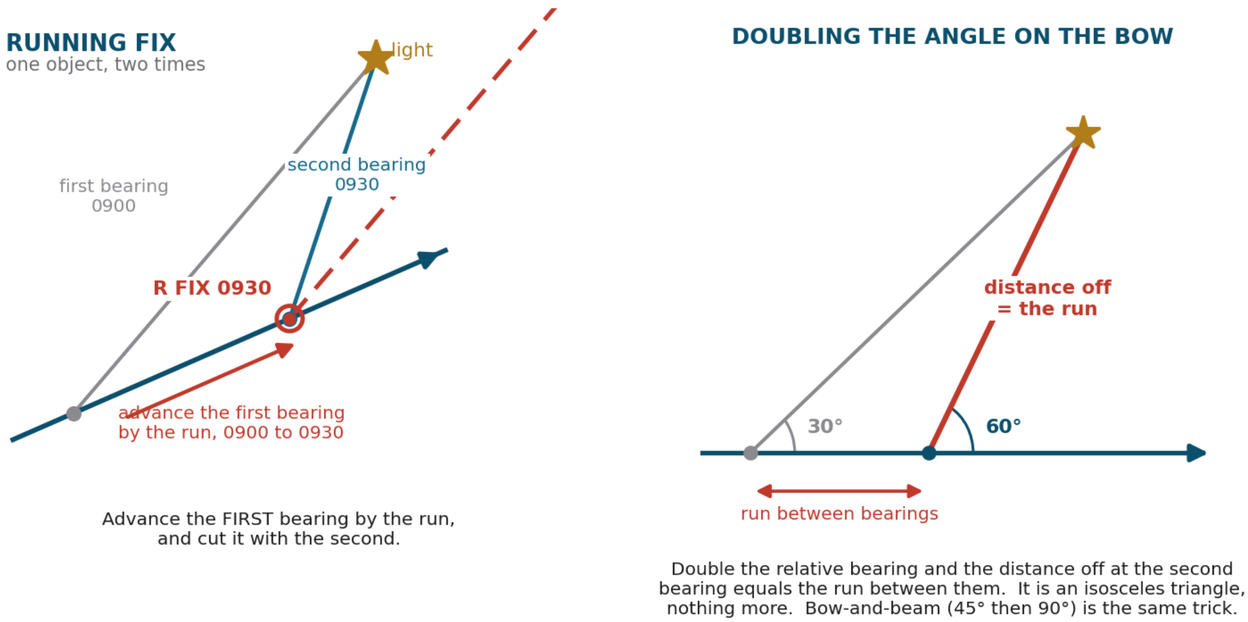
The plotting conventions are marked in the chart plot examination, so learn them as rules rather than habits.

- A **DR position** is advanced from a known position using **course steered and speed through the water, and nothing else**. Not the current, not the leeway.
- Plot a new DR at every change of course, every change of speed, every hour on the hour, and at every fix.
- A **fix** is an observed position — circle it. A **DR** is a semicircle. An **estimated position**, which is a DR with set and drift or leeway applied, is a square.
- Label the course **above** the line in three figures true, and the speed **below** it. Times go in four figures.

SECTION 4

Fixing your position

Three ways that need one object, and one that needs three.



Left: the running fix, when only one thing is visible. Right: the isosceles triangle that gives you a distance off for free.

Bearings

Two lines of position cross at a point; three tell you whether to believe it. Three bearings that meet at a point are a good fix. Three that make a small triangle — a **cocked hat** — are still usable, and you take the position as the corner nearest the danger. A large cocked hat means something is wrong: a misidentified mark, a compass error, or too long between the first bearing and the last. **Shoot the object changing bearing most slowly first, and the fastest last.**

For the best cut, choose objects about **60 to 120 degrees apart** for two, or roughly **60 degrees apart** for three. Two objects nearly in line give a shallow intersection where a small bearing error becomes a large position error.

Distance off without a range

Method	How	What you get
Doubling the angle on the bow	Note the relative bearing. Steady on. When the relative bearing has **doubled**, note the run between the two.	The **distance off at the second bearing equals the run**. It is an isosceles triangle
Bow and beam bearings	The special case: take the bearing at **45°** relative, then at **90°**	The distance abeam equals the run between them — and you get the distance at the exact moment she is abeam
Vertical sextant angle	Measure the angle subtended by a light of known height	Distance from Bowditch Table 15, or distance (NM) = 0.565 × height (ft) / angle (minutes)
Radar range	A range arc from a positively identified object	A radar **range** is far more accurate than a radar **bearing**. Prefer two ranges to two bearings

The running fix

When only one object is visible, take a bearing, run on, and take another. **Advance the first line of position by the course and distance run between the two**, and where the advanced line cuts the second you have a running fix. Label it **R FIX** with the time of the *second* bearing.

> **A running fix is only as good as the run you put into it.**
>
> The advance uses your **DR** run — course and speed through the water. If there is a current setting you off, that error goes straight into the fix, and a running fix in a strong tidal stream can be badly out.
>
> Treat it as better than a DR and worse than a real fix, and never use one to clear a danger if you can get anything better.

Staying off the rocks

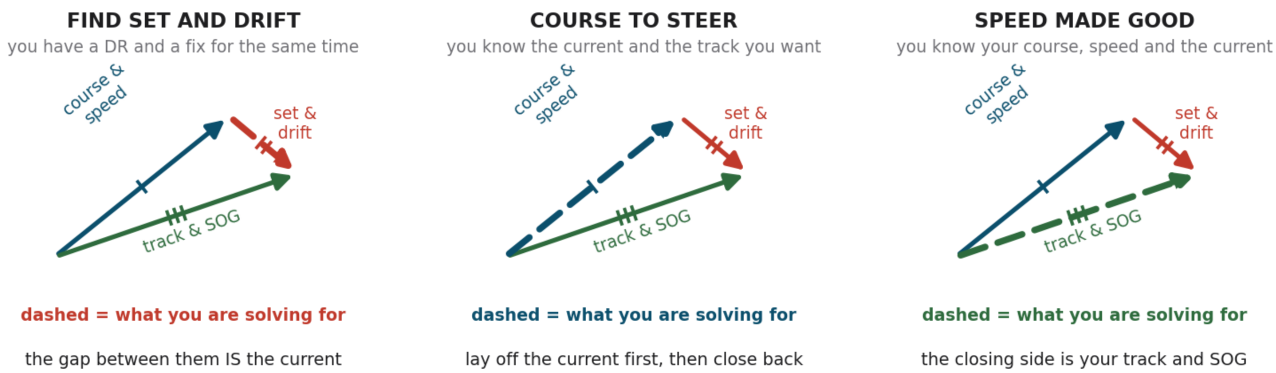
A **danger bearing** is a single line drawn from a charted object so that it just clears a hazard, marked **NMT** or **NLT** — not more than, or not less than, that bearing. Keep the actual bearing on the safe side of it and you are clear, with no plotting at all. A **danger circle** does the same job with a radar range, and a **danger sounding** with the echo sounder. All three are decisions made in advance so that nobody has to make them under pressure.

SECTION 5

Set and drift

One triangle, three questions. Which side you are missing decides which question it is.

Set is the direction the current flows **toward** — the opposite convention to wind, which is named for where it comes from. **Drift** is its speed in knots. Together they are the difference between where the water takes you and where you steered.



One tick = through the water. Two = the current. Three = over the ground. Mark them and the triangle cannot get away from you.

The same triangle every time. The only thing that changes is which side you are solving for.

You have	You want	How
A DR and a fix for the **same time**	Set and drift	The line from the DR to the fix **is** the current. Its direction is the set; its length divided by the hours run is the drift
The track you want, and the current	The course to steer	From the start, lay the current off first. From the end of it, swing your speed as a radius to cut the desired track. That leg is the course to steer
Your course and speed, and the current	Track and speed over the ground	Lay course and speed, then the current from its end. The closing line from start to finish is the track made good, and its length is the speed over the ground

Two conventions that keep it straight

Arrowheads and ticks. One tick on the water track (course and speed steered), two on the current, three on the ground track. Mark them as you draw and the triangle cannot get away from you.

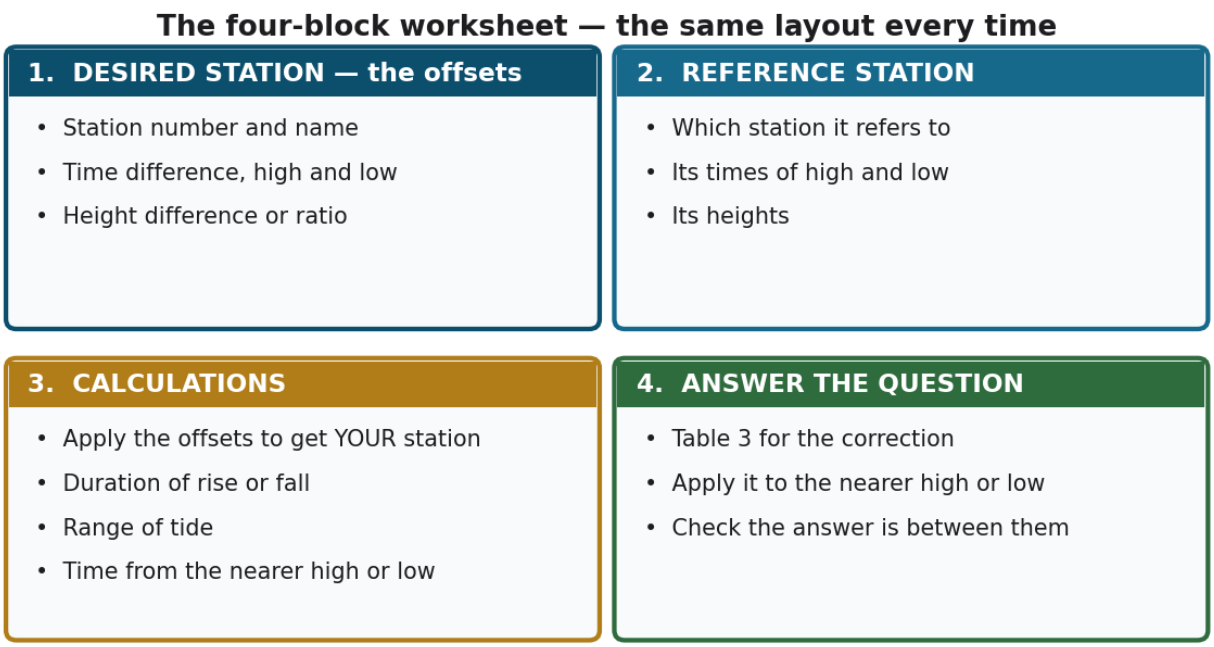
Speed made good is not speed through the water. If the question asks for an ETA it wants the ground track; if it asks what to ring on for, it wants the water track.

SECTION 6

Tides

Your four-block method, and the arithmetic that sits underneath Table 3.

A **reference station** has full daily predictions. A **subordinate station** has none — it has a set of differences you apply to a named reference station. Almost every exam question is at a subordinate station, which is why the first thing you do is build your own station out of somebody else's.



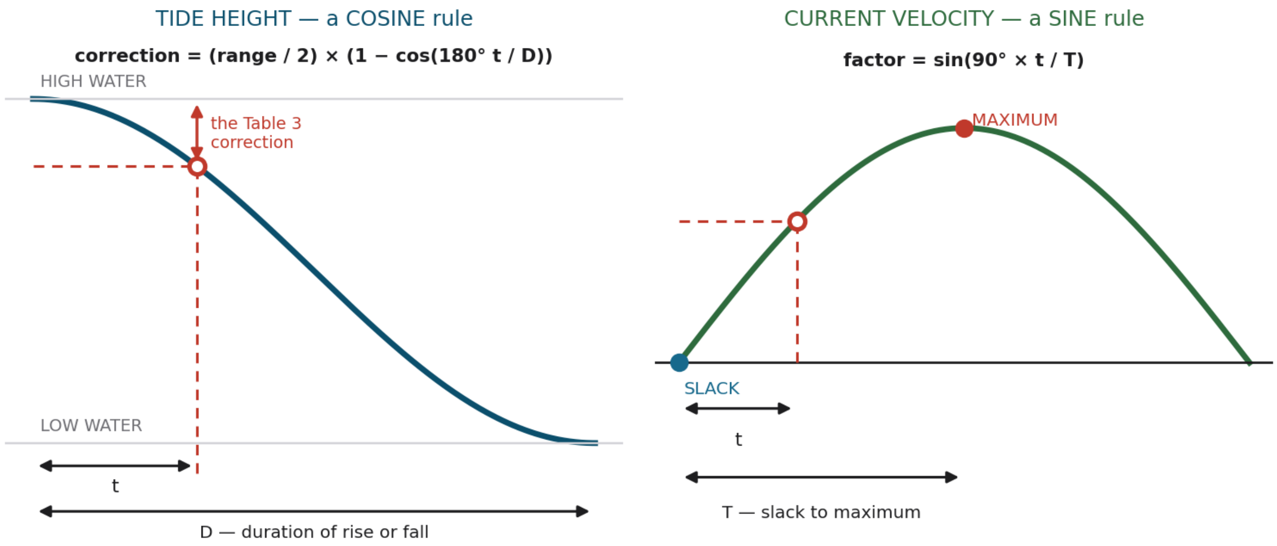
The same four blocks every time. The discipline is the point: it is what lets you find your own mistake when the answer is not one of the four offered.

The tables are in LOCAL STANDARD TIME. Always.

If the question gives you a daylight-time and a zone description — 1105 DST (ZD +4), say — convert it back to standard time **before you start**: 1005 (ZD +5). Work the whole problem in standard time and, if the question wants the answer in daylight time, convert once at the very end.

This single step accounts for more wrong answers on tide questions than the interpolation does.

What Table 3 actually is



Two different curves for two different things. Reading a tide problem with the current rule, or the reverse, is a common and expensive slip.

> ### The tide rule
>
> **correction = (range / 2) × (1 – cos(180° × t / D))**
>
> **D** = duration of rise or fall — the interval from the high to the low that brackets your time. **t** = the interval from the *nearer* of those two to the time you want. **Range** = the difference between that high and that low.
>
> Then apply the correction to the **nearer high or low** — subtract from a high, add to a low.
>
> *Table 3 does this for you. Knowing what it is doing is how you catch yourself when the answer comes out impossible.*

Worked: your TC D1

Height of tide at Three Mile Harbor Entrance, Gardiner's Bay, on 14 November at 0700 (ZD +5)?

Block	Working
1. Offsets	Station 1399: high +0:21 and –0.2 ft; low +0:02 and 0.0 ft
2. Reference	New London — high 0453, 2.2 ft; low 1108, 0.5 ft
3. Your station	High 0453 + 0:21 = **0514**, 2.2 – 0.2 = **2.0 ft** Low 1108 + 0:02 = **1110**, 0.5 + 0.0 = **0.5 ft** Duration of fall = 1110 – 0514 = **5h 56m** · range = 2.0 – 0.5 = **1.5 ft** · t from the high = 0700 – 0514 = **1h 46m**
4. Answer	Table 3 gives **0.3 ft**. Check it: (1.5/2)(1 – cos(180 × 1.767/5.933)) = 0.30. Nearer to the high, and the tide is falling, so subtract: 2.0 – 0.3 = **1.7 feet**

Working it backwards

The harder version asks for the **time** at which the tide will reach a given height — your TC D3, South Freeport. Build the station exactly the same way, then work Table 3 in reverse: you know the correction you need, so you enter with the duration and the correction and read out the interval from the high or low.

TC D3 in outline

High 1237 at 10.0 ft, low 0623 at –0.2 ft → duration of rise **6h 14m**, range **10.2 ft**

You want 6.0 ft, so you need a correction of 10.0 – 6.0 = **4.0 ft** below the high

Reverse Table 3 with duration 6:14 and correction 4.0 in a range of 10.2 → interval **2h 45m**

1237 – 2:45 = **0952**

The formula gives 2h 41m, four minutes different, because Table 3 is tabulated in coarse steps. Use the table — it is what is being marked.

SECTION 7

Tidal currents

Same worksheet, different curve, and everything measured from slack.

Tidal current tables work exactly like tide tables — reference stations, subordinate stations, time differences — with two differences that matter. The velocity offsets are **ratios**, not additions. And everything is measured from **slack water** rather than from a high or a low.

> ### The current rule
>
> **factor = sin(90° × t / T)**
>
> **T** = the interval from slack to the maximum either side of your time. **t** = the interval from that slack to the time you want.
>
> **velocity = maximum × factor**
>
> It is a sine, not a cosine, because the current is zero at slack and maximum a quarter-cycle later — whereas the tide is at an *extreme* at high and low water.

Worked: your TC D4

Velocity of the tidal current 2 miles west of Southwest Ledge, RI, on 7 September at 2330 EDT (ZD +4)?

Block	Working
0. Time	2330 EDT (ZD +4) is **2230 standard** (ZD +5). Work in standard time
1. Offsets	Station 2216: slack before flood +0:02, flood +0:10 and **×0.5**, slack before ebb +0:01, ebb –0:41 and **×0.5**
2. Reference	The Race — maximum flood 2037 at 4.3 kt; slack 2342
3. Your station	Maximum flood 2037 + 0:10 = **2047**, 4.3 × 0.5 = **2.15 kt** Slack 2342 + 0:01 = **2343** T, slack to maximum = 2343 – 2047 = **2h 56m** · t, slack to the time wanted = 2343 – 2230 = **1h 13m**
4. Answer	Table 3 gives **0.6**. Check it: sin(90 × 1.217/2.933) = sin 37.3° = 0.61. 2.15 × 0.6 = **1.3 knots**

Two more kinds of current question

Duration of slack — how long the current stays below a stated value — comes from **Table 4**, entered with the *average* of the maximum before and the maximum after. Your TC D5: maxima of 1.4 and 2.2 knots average to 1.8; Table 4 gives 15 minutes at 1.5 knots and 11 minutes at 2.0, so interpolating gives **13 minutes**.

Current diagrams answer the question ‘where will I lose the fair tide?’ for the big rivers — Delaware Bay, Chesapeake Bay, the East River. You enter with your speed, your starting point and how long before or after the reference slack you get under way, and read off where you are when the current turns. Your TC D6 is exactly that: under way 34 minutes after the flood begins at the entrance, making 8 knots southbound, and the diagram gives mile 63.

SECTION 8

The tear-out card

The whole of coastal piloting that has a rule attached to it.

TIDES AND CURRENTS

The tables are in LOCAL STANDARD TIME. Convert daylight time back one hour before you start.

Tide: correction = (range/2) × (1 – cos(180° t / D)) — a COSINE. D = duration of rise or fall, t = from the nearer high or low. Subtract from a high, add to a low.

Current: factor = sin(90° t / T) — a SINE. T = slack to maximum, t = from slack. velocity = maximum × factor.

Tide offsets are **added**. Current velocity offsets are **ratios**.

Duration of slack: **Table 4**, entered with the average of the maxima either side.

SET AND DRIFT

Set is the direction the current flows TOWARD. Drift is its speed.

DR to fix = the current. Direction is the set; distance ÷ hours is the drift.

Course to steer: lay the current off first, then swing your speed to cut the desired track.

One tick = water track · two = current · three = ground track.

FIXES

Doubling the angle on the bow: distance off at the second bearing = the run between them.

Bow and beam (45° then 90°): the distance abeam = the run.

Running fix: advance the first LOP by the course and distance run; label it with the time of the SECOND bearing.

Vertical sextant angle: distance (NM) = 0.565 × height (ft) / angle (minutes), or Bowditch Table 15.

Shoot the **slowest-changing bearing first**. Radar RANGES beat radar BEARINGS.

Cocked hat: take the corner **nearest the danger**.

PLOTTING AND AIDS

Circle = fix · **semicircle** = DR · **square** = estimated position.

Course **above** the line, speed **below**. A DR uses course and speed ONLY.

Distances come off the **latitude** scale at the side, never the longitude scale.

Red right returning — red, nun, even to starboard; green, can, odd to port. IALA Region B. Numbers increase from seaward.

US charts sound to **mean lower low water**; Admiralty charts to **lowest astronomical tide**.

IF YOU ONLY REMEMBER ONE THING

Build your own station out of the reference station first, and write down all four blocks even when you think you can do it in your head.