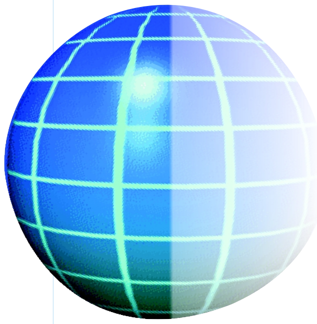

working with TIDES

by Keith Belfield

Working with Tides

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written by Keith Belfield

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Introduction

Working with Tides has been written by the authors of Tide Plotter, the computer tide prediction program.

This book explains what creates the tide raising forces, how tides work and how they affect us around our shores and on the sea. The theory of tides is explained and there are many exercises aimed to put knowledge into practice.

Whilst the authors originally put their knowledge into the code of a computer program in order to take out all the hard work of calculating tide information, it is also acknowledged that this does not substitute being able to do it yourself.

If you have need to either venture out onto our tidal waters, or, access the tidal reaches of our shores, then the information contained in this book will give some background knowledge to assist you do it in a planned and controlled manner. The enormous power of the tide can never be underestimated, or taken for granted. *'Time and tide wait for no one,'* we have never been able to stop, or even delay the tides, but we can certainly use our knowledge to harness their great power to best benefit. If King Canute had only known when he tried to command the tide not to come in that it was not the tide itself which was being insubordinate, but these twin travellers of the sky, the Sun and the Moon. It is these two celestial objects which dominate our skies controlling the movement of the tide.

Tides a definition

The word ‘tides’ defines the alternating rise and fall in sea level with respect to the land.

It was one of the many triumphs of Newton to demonstrate that the daily ebb and flow of the waters of the ocean, which we call the tides, are due to the gravitational attraction of the sun and the moon.

The endless ebb and flow of the water on the earth’s surface is one of our great natural forms of energy. The fluid nature of the water result in the movement and ever changing nature of our oceans. The sea levels change daily as the sun, moon and earth interact. As the moon orbits the earth and they, together, orbit around the sun, the combined gravitational forces pull and the world’s oceans rise and fall.

What causes tides? Why is there a daily change? Why are some tides higher than others and what are the implications for animals, plant life and the people who live, work on or near the oceans? This book will answer some of these questions and give some practical applications on how to calculate and predict the actions of the tides.

The knowledge of tides is vital for virtually all people who live or work either on or near our tidal waters; such functions as navigation, fishing, construction, research, and leisure are just a few of the activities that depend upon the knowledge of tides. Calculating heights and cycles of movement enable us to work and play effectively and safely. Exercises in the calculation of tides are given at the rear of this book.

Why do we need to understand tides?

There are numerous examples of the benefits of having an understanding of tides: Some harbours can only be entered at certain heights of the tide, crossing a sandbank can be hazardous during certain parts of the tide cycle; the current created by the tide can be an obstacle or used to advantage. There is both an enormous danger in venturing on or around tidal areas plus the benefit of being able harness the use of tides to our advantage.

Predicting tides

Prediction of tides is not an exact science, there are a lot of variable factors that can cause change to their pattern. However, by utilising astronomical data and surveying the various constants around our shores it is possible to fairly accurately predict the patterns of tides and the currents created by them.

Whilst it is possible to predict astronomical data centuries in advance, meteorological conditions, that can produce large variations to the tidal movement, can only be predicted a few days in advance. A perigean high tide, when the moon is at its closest to the earth causing particularly high tides, combined with severe weather, can cause flooding and enormous damage from surge tides and abnormally high water conditions. Examples of this are fairly common; the floods on the east coast of England in 1953, caused by the strong easterly winds piling the water onto the shore. The Blizzard of 1978 on the coast of America was another example. Storm surges are caused by strong onshore winds and low atmospheric conditions. By becoming more informed about the predictability of the astronomical tides we can become better prepared for the unpredictable elements of nature.

Woodbridge - entry to and from is only possible during the higher parts of the tide.

Historical facts

As with many things related to the sea and nautical development, there are no precise dates and facts as to when it all started. There is, however, evidence of the knowledge of tides as far back as 2450 BC. This knowledge demonstrates the fact that seafarers were conversant with tides in a practical sense but it was much later in time that there was evidence of an understanding of the theory behind tides and that the cause of tides related to the sun and moon.

As we moved through history many mthys existed around this mysterious rising and falling of the sea. For example: no animal dies except when the water is ebbing, the premise that life ebbed out of the body at the same time the water ebbed from the sea. This concept survived through ancient cultures through to modern times. In the 16th Century in the North of England the state of the tide was recorded with each death. The Chinese, for many years, believed the the water is the blood of the earth and the tides were caused by the earth breathing.

2450 BC
Excavations in India revealed Naval dockyards with tidal gates

2000 BC
Evidence was found that related the local tidal movements to the moon or the sun. This connection can be found in the Samaveda of the Indian Vedic period (2000-1400 BC).

322 BC
Whilst the Mediterranean is not reknowned for its tides, there is evidence that the reversals of flow between the mainland of Greece and the island of Euboea surprised Aristotle. Before his death in 322 BC Aristotle wrote that the "*ebbings and risings of the sea always come around with the moon and upon certain fixed times*''. At the same time Pytheas travelled through the Strait of Gibraltar to the British Isles and reported the half-monthly variations in the range of the Atlantic Ocean tides, and that the greatest ranges (spring tides) occurred near the new and full moon.

AD 735
Venerable Bede was familiar with the tides along the coast of Northumbria, and was able to calculate the tides using the 19-year lunar cycle. Tide tables and diagrams showing how neap and spring tides alternate were

appearing in several manuscripts. The ability to predict tides became a source of income for those who knew the secret.

1550 - 1650 AD

Different theories on the tide raising forces were starting to emerge and be taken seriously:

Galileo had the theory that the earth rotating about its own axis and the annual rotation around the sun produced motions of the sea; this along with the shape of the sea bed gave rise to tides.

Descartes thought that space was full of invisible matter and as the moon travelled around the earth it compressed the matter in a way which transmitted pressure to the sea, hence forming the tides.

Keppler was one of the originators of the idea that the moon exerted a gravitational attraction on the water of the ocean, drawing it towards the place where it was overhead. This attraction was balanced by the earth's attraction on the water. He stated that if the earth should ever cease to attract its waters, the sea would be elevated and flow into the body of the moon.

1642 - 1727 AD

A major step forward in the understanding of tides was made by Isaac Newton. He was able to apply his formulation of the law of gravitational attraction in demonstrating why there were two daily tides for each lunar transit. He also solved the explanation of why some tides were higher than others, or as we now know them, spring and neap tides.

1833 AD

The harmonic method of tide prediction was developed and in 1844 the first official predictions for four ports, (Plymouth, Portsmouth, Sheerness and London Bridge,) were published by the British Admiralty.

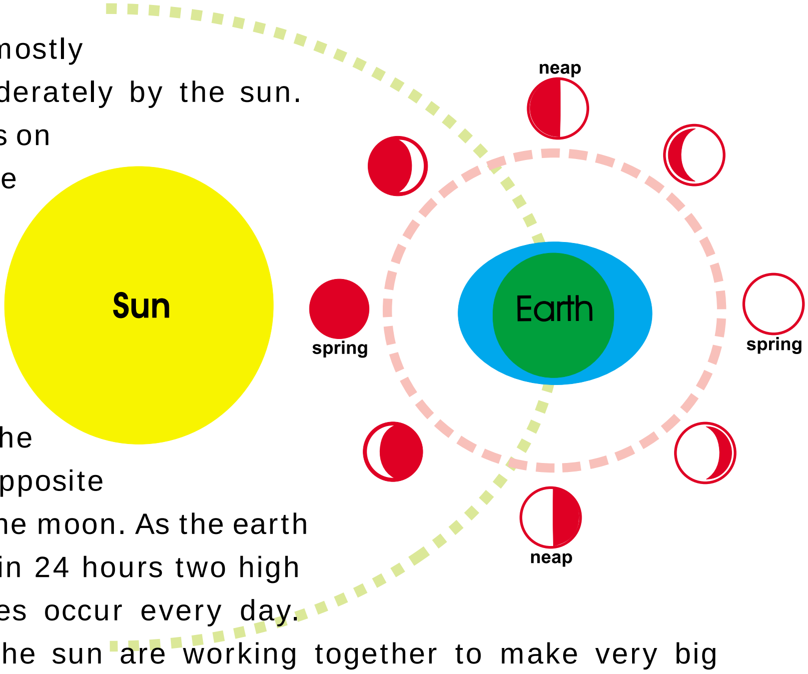
1873 AD

The development of tide predicting machines. Sir William Thomson, the future Lord Kelvin, constructed a machine to calculate tides. This machine was in use up to the year 1965 and was then superceeded with the use of computers.

Kelvin Tide Predicor

Sun, Earth, and Moon in Motion

The Sun is at the centre. The Earth orbits around the Sun, and the Moon orbits around the Earth. The Earth also rotates about an axis as it spins.



The tides are caused mostly by the moon, and moderately by the sun. The moon's gravity pulls on the Earth, causing a bulge of water. The Earth then spins beneath this bulge of water, causing the tides. There is a bulge at the side of Earth facing the moon, and the exact opposite side facing away from the moon. As the earth rotates one revolution in 24 hours two high tides and two low tides occur every day. When the moon and the sun are working together to make very big tides, the effect is called Spring Tides. When they are working against one another (at right angles to one another) to produce smaller tides, the effect is called Neap Tides.
The movement of the water on the earth's surface is caused by a combination of forces. The two main and most significant ones being gravitational pull exerted by the moon and sun, plus the centrifugal forces produced by the revolutions of the earth and moon and earth and sun.

Tides can occur on any water mass on the earth's surface, for example, lakes. The movement, however, on small masses of water is so imperceptibly small that the effect bears no consequence.

Other non astronomical factors can also have a considerable bearing on the movement of water caused by the tide raising effect. If you were in the middle of the Atlantic you would not notice the rising and falling of the tides, which incidentally has a much smaller range than our coastal waters. Along our shores the shape of the land, topography, and the depth of the water, bathymetry, play a significant role in the way in which the water moves as a result of the tide raising forces. Such features give rise to many of the phrases: tidal gates, overfalls, and races etc. Water funnelling up estuaries or being heaped up around prominent headlands can have amplified effects.

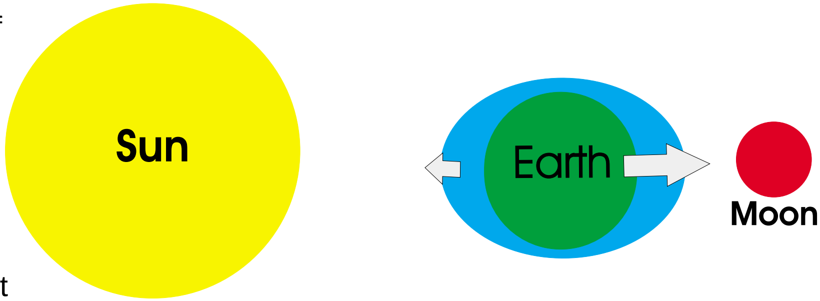
Extreme examples of the effect of the shape of the coast and the depth of water can be found in such places as the Bay of Fundy, between Nova Scotia and New Brunswick in Canada. This coast experiences the world's greatest tidal range in excess of 50 ft. (15.25 metres). To put this into some form of perspective look up at a five storey building and imagine the sea rising and falling through this incredible range every 12 hours and 26 minutes. This water movement is equivalent to all the flow of the rivers worldwide. Tides also cause a resonance, the rhythmic in and out motion; it has the effect of amplifying their height. This is similar to the water moving back and forth in a regular rhythm, as in the bath when you move back and forth, this rhythm can magnify the tidal effect. In the bay of Fundy the effect is most pronounced at the end in the Minas Basin.

The Bay of Fundy tides are one of over 30 locations where the power of the tides is harnessed to generate electricity. In the UK the Bristol Channel is a good example of exceptionally high tides, caused by the funnel shape of the channel. These, and many other areas of exceptional high tides, create the phenomena of a tidal bore or wall of water that moves up the channel. The Bristol Channel creates the Severn bore which is particularly noticeable on the high tides of the Spring and Autumn equinox; surfers and canoeist line up to surf the bore and the Guinness Book of Records notes the longest ever ride on a single wave.

The moon is four hundred times closer to the earth than the sun and as a consequence has far greater influence on the tides than the sun. As the moon orbits the earth, tidal bulges occur, or to put it another way the water heaps up, the water nearest the moon is pulled towards it. The gravitational pull tries to draw both the solid mass of the earth and the water on its surface towards it. The solid mass of the earth resists this pull, without which, we would have been on a collision course a long time ago; the fluid nature of the water on the earths surface is unable to completely resist this pull and a bulge occurs as the moon pulls the water towards it. On the opposite side of the earth a second bulge occurs, these bulges create high tides and between them there is a low tide. Usually there are two high and low tides occurring each 24 hours and 52 minutes. The alternation of high water and low water is caused by the daily (or diurnal) rotation of the earth.

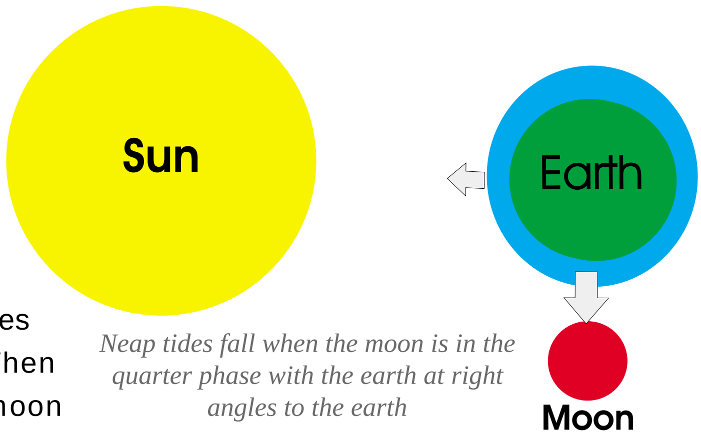
More detailed explanation of the basic astronomical factors which produce tides and tidal currents can be found on the Centre for Operational Oceanographic Products and Services (CO-OPS) website: http://www.co-ops.nos.noaa.gov

The difference in height between high and low water occurring at a given place is known as the tidal range, The range is a very key component in the calculations of the speed of the flow of water around our coast. The range of tidal movement will vary each day, each month, each year and the full cycle of change takes 18.6 years to complete. On this basis it would be worth bearing in mind that if you run aground it could take 18 years to float off again!



Spring tides fall when the moon is in line with the sun and earth

The factors that affect this range are:
Astronomical lunar effect, causes spring and Neap tides. The changing position of the moon in relation to the sun and earth during the monthly cycle, 29.53 days. The gravitational pull of the moon and sun vary as they are at changing angles relative to each other. When there is a new or full moon the gravitational pull of both the sun and moon work directly together, this increased gravitation pull causes the greatest range in tides and these tides are called ‘Spring’ tides, a term that just means a ‘welling up’ of the water and has no bearing on the season of the year.



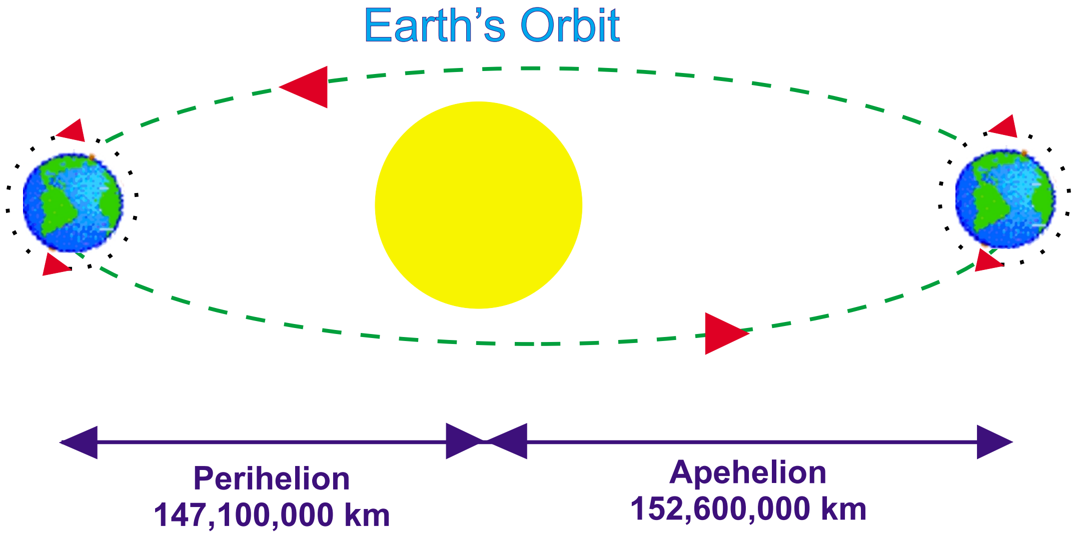
Neap tides fall when the moon is in the quarter phase with the earth at right angles to the earth

At the first and third quarter of the cycle the gravitation of the sun and moon are no longer in line with one another but are at right angles to one another with the gravitational pull of each one countering the other; thus the range of the tide is considerably reduced. Such tides of less than average range are known as 'Neap' tides; again the word neap, having nothing to do with Scottish food, but originating from a Greek word meaning 'scanty'.

The movement of the moon around the earth is not circular but elliptical, thus the distance between the two bodies will vary by about 31,000 miles. When the moon is closest to the earth (perigee) the tide raising forces will be greater. Approximately two weeks later the forces will be less when the moon is further away from the earth (apogee), with below average tidal ranges. The same effect occurs with the sun on an annual basis, with the sun being closest to the earth (perihelion), around 2 January of each year, increasing the tidal range and conversely when the earth is farthest away from the sun (aphelion), around 2 July, the tidal range will be smaller.

When perigee, perihelion, and new or full moon all occur at the same time the tidal range will be considerably increased. Likewise, apogee, aphelion with the 1st or 3rd quarter occurring together, then the tidal range will be very small.

The full effect of, a spring tide for example, is not felt exactly when the sun and moon are in line, e.g.., a full moon. This is because there is a certain inertia with the large amount of water swilling around our earth; the momentum of the gravitational pull continues and it takes approximately a further two days for the tide to reach its highest and lowest. If you look at your tide tables and determine the predicted height at full moon you will notice that the range continues to increase for a further two days before it starts to decline again.

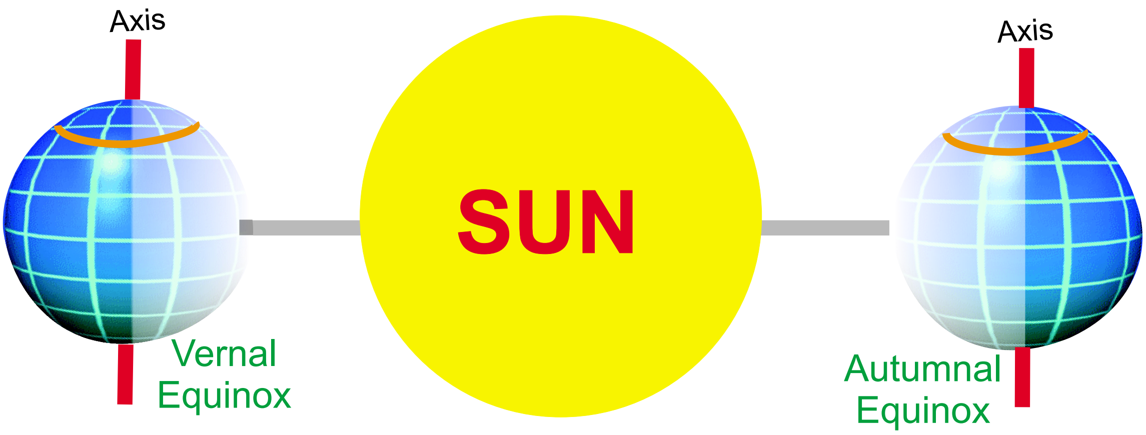


Equinox

Big tides occur during the equinox period.

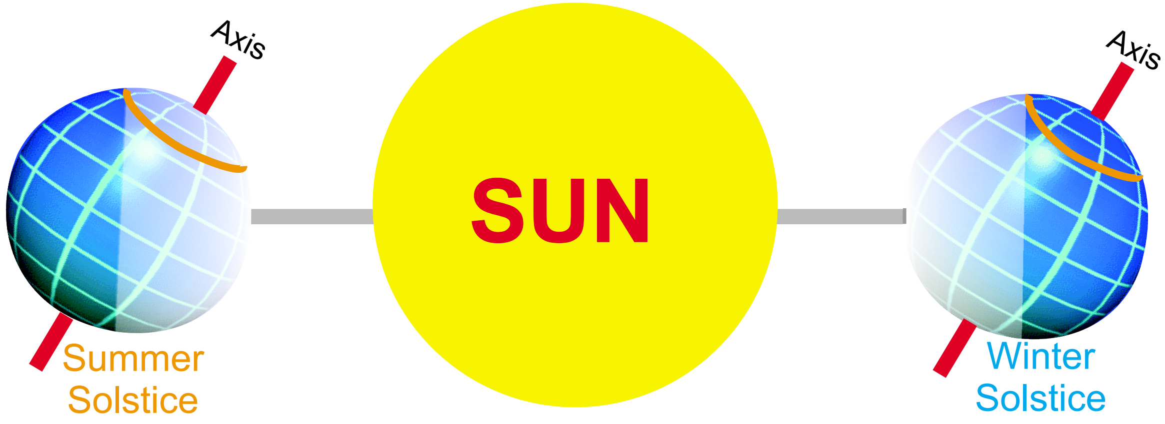
Each day after the winter solstice, which occurs on December 21st, the Sun's path becomes a little higher in the southern sky. Spring Equinox is the point in the year when the sun crosses the equator travelling from the south to the north, declination zero degrees. The Sun also begins to rise closer to the east and set closer to the west until we reach the day when it rises exactly east and sets exactly west. This day is called the equinox. In the spring we have the Vernal (Spring) Equinox at about March 21st. There is also an Autumnal Equinox on September 21st

Spring Equinox marks the beginning of Spring and the time when days and nights are of equal length.



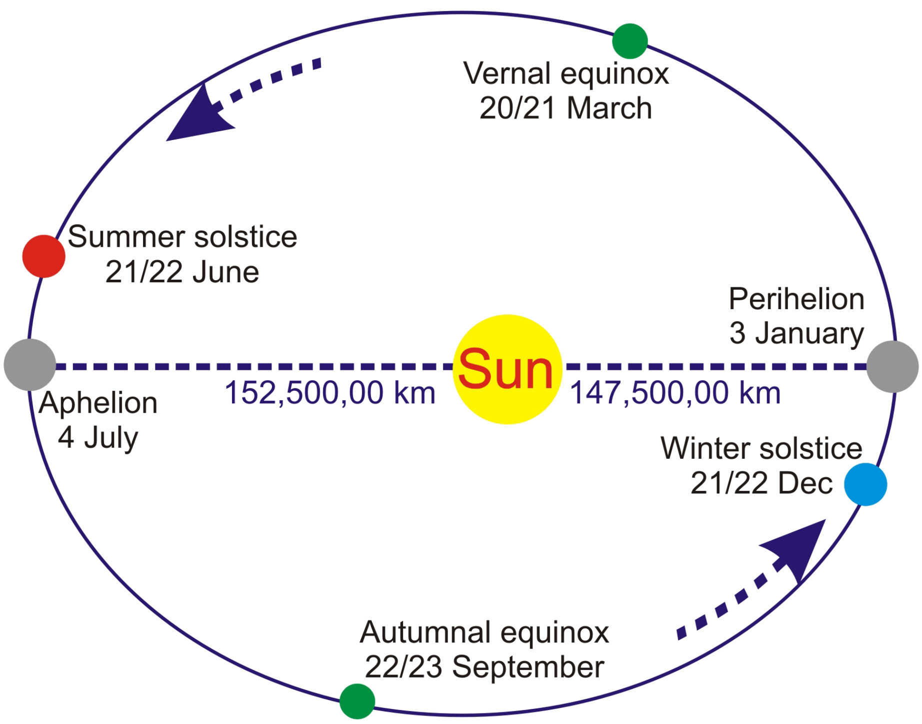
Angle of declination zero degrees, sun rises in the East and sets in the West, equal day and night. It is during this period vernal and autumnal equinoxes that we experience the largest tides

On June 21 or 22, the summer solstice is when the Earth is positioned such that the North Pole is leaning 23.5 degrees toward the sun (see adjacent page.) North of the equator we have daylight greater than twelve hours, while South of the equator we have daylight less than twelve hours. On December 21 or 22, the winter solstice, the Earth is positioned such that the South Pole is leaning 23.5 degrees toward the sun. During the winter solstice, the day lengths of daylight are shorter in the Northern Hemisphere.



It is also worth noting, the diagram illustrates why we get constant daylight in the Artic Circle; look at the orange circle on the top of the globe. The 23.5 degrees tilt of the north towards the sun puts the top of the earth constantly in view of the sun. This phenomenon keeps all places above a latitude of 66.5 degrees N, the Artic circle, in 24 hours of sunlight. Equally you can see from the right hand globe with north tilted away at winter solstice, that the Artic circle will be constantly in darkness. To summarise: for the northern hemisphere, the further north in the summer the greater the period of daylight and the greater period of darkness in the winter.

The earth orbiting the sun



The earth orbits the sun in an anticlockwise direction, the time taken is 365.25 days (plus a few very minor adjustments every few hundred years).

The Moon

The Moon is the only natural satellite of Earth:

orbit:	384,400 km from Earth
diameter:	3476 km
mass:	7.35e22 kg

Called Luna by the Romans, Selene and Artemis by the Greeks, and many other names in other mythologies.

The Earth's Moon, of course, has been known since prehistoric times. It is the second brightest object in the sky after the Sun. The fifth largest in the whole solar system, and is bigger than the planet Pluto. The Moon has a nearly circular orbit which is tilted about 5° to the plane of the Earth's orbit. As the Moon orbits around the Earth once per month in a counter-clockwise direction, which is the same direction that the Earth rotates, the angle between the Earth, the Moon and the Sun changes; we see this as the cycle of the Moon's phases.

There are two different ways to measure a lunar month, sidereal and synodic. The sidereal month is the time it takes for the Moon to complete one full orbit of the Earth, measured with respect to the distant stars. The major assumption in determining a sidereal month is that the distant stars are fixed relative to Earth, and for the most part they are stationary. The sidereal month is the Moon's true orbital period and is equal to 27.3 days. That is, it takes the Moon 27.3 days to be in the same position relative to the distant stars.

The synodic month is the time it takes for the Moon to complete one cycle of phases. That is, the time between successive new moons. Therefore the synodic month is measured with respect to the Sun and is approximately 29.5 days.

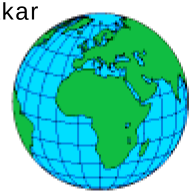
Why is there a difference between the sidereal and synodic periods? Well, the Earth keeps orbiting the Sun while the Moon is going through its phases. Thus, to go from one new moon to the next the Moon must travel more than 360° along its orbit. The synodic month is therefore approximately two days longer than the sidereal month.

The Moon was first visited by the Soviet spacecraft Luna 2 in 1959. It is the only extraterrestrial body to have been visited by humans. The first landing was on July 20, 1969 (do you remember where you were?) The last was in December 1972. The Moon is also the only body from which samples have been returned to Earth. In the summer of 1994, the Moon was very extensively mapped by the spacecraft Clementine and again in 1999 by Lunar Prospector.

Time zones

It is important to understand how time zones relate to the tide data that you will be accessing. There are many differences between tidal data and real time. In the UK most Almanacs and Tide Tables use (UT) Universal time. (GMT) Greenwich Meantime and UT can be taken as the same.

Each time zone covers 15º of longitude. Thus 360º /15º = 24, the number of time zones. The zero time zone is Greenwich Mean Time and extends 7½º East and 7½º West of Greenwich. Time zones are numbered and a minus sign precedes the value if East of Greenwich, and plus West of Greenwich. Confusion can occur sometimes as whether to add or subtract to the time given in the Almanac in order to ascertain the real time. If you apply the zone time to the time given in the Almanac you will get UT / GMT. Example: if the time given is 2300 hrs. and the time zone is -0100 then UT / GMT is 2300 – 0100 = 2200 hrs. If you were in British Standard Time or Continental Standard Time then you would have to add one hour to get the real time from the Almanac. Almanacs and tide tables state the time zone and when you have to add or subtract to get the real time. The boundaries of the 15º longitude for each time zone are not strictly adhered to as there would be a certain inconvenience in splitting an area time wise by a geographical line. Also hours are often added during the summer months to give longer periods of daylight, e.g.., BST – British Summer Time, or Daylight Saving Time on the Continent.

	Zone	Time	City	
GMT	Greenwich Mean Time	0000	GMT	London, Dublin, Reykjavik, Lisbon, Dakar
BST	British Summer Time	-0100	GMT+1hr	
IST	Irish Summer Time	-0100	GMT+1	
WET	Western Europe Time	0000	GMT	
WEST	Western Europe Summer Time	-0100	GMT+1	
CET	Central Europe Time	-0100	GMT+1	Paris, Berlin, Lagos
CEST	Central Europe Summer Time	-0200	GMT+2	
EET	Eastern Europe Time	-0200	GMT+2	Kiev, Cairo, Johannesburg
EEST	Eastern Europe Summer Time	-0300	GMT+3	
MSK	Moscow Time	-0300	GMT+3	Moscow, Baghdad, Nairobi
MSD	Moscow Summer Time	-0400	GMT+4	

Tidal Phenomena

The movements of seas and oceans can be produced by the wind, the differences of temperature of the water, the passage of the Moon and Sun, the movements of the oceanic crust.

The usual effects are : waves, swell, ocean currents, tides. But when currents act against each other, the turbulent currents can become dangerous. The following are examples:

- Maelstroms at sea, whirling ocean currents;
- Tidal bore, when the tide makes a wave ascend a water course;
- Zone of turbulence, formed at the outlet of a river in the sea

Tidal waves

Tidal waves (or tsunami) are movements of water propagating at high speed (800 km / hour) and crashing on coasts in the form of a wave being able to achieve 30 metres in height. They originate in submarine earthquakes. The tsunami of July, 1998 caused more than 2 000 deaths and destroyed seven villages in Papua New Guinea. On Boxing Day 2004 one of the largest tsunami's ever devasted a large part of the Asian Continent around the bay of Bengal.

Sometimes, submarine avalanches can provoke small tidal waves.

In October, 1979, a submarine avalanche in the mouth of the Var provoked a tidal wave which destroyed a part of the airport of Nice (France) and caused several deaths.

The most recent and by far the largest disaster caused by tidal wave movement was the tsunami in the Indian and surrounding oceans, it occurred on Boxing Day 2004. The chain reaction that set off enormous, deadly tsunami waves that struck seven nations in Asia and one in Africa started kilometres beneath the ocean floor off the tip of the Indonesian island of Sumatra.

Geologic plates pressing against each other slipped violently in magnitude causing a 9.0 quake on the Richter Scale, creating a bulge on the sea bottom as high as 10 metres and as long as 1200 kilometres.

Storm tides

These occur as an exceptional rise of the sea level due to a storm. This is in excess of the normal tide.

It is the most deadly maritime phenomenon. Bengal is one of the regions of the world most exposed.

- (In 1876 following the passage of the cyclone Bakergary, a storm tide caused about two million deaths in Bangladesh.)
- (In November, 1970 a storm tide caused about 300 000 deaths in the Ganges delta.)

The highest recorded storm tide was in March, 1899 in Bathurst Bay (in Galveston, Texas, in 1900 a wind velocity of more than 100 mi (160 km) per hr, combined with low barometric pressure, caused tides 15 ft (5 m) above normal that flooded coastal areas, resulting in the loss of thousands of lives and extensive property damage.

There are many ocean disasters that happen because of tidal waves. In order to understand tidal waves, we need to know a little bit about ocean waves in general. Currents, tides, and waves keep the oceans moving. The spinning of the earth, and the pulling of the sun and moon cause tides. Wind causes most of the waves in the ocean. But tidal waves are different. Tidal waves are big, fast, destructive ocean waves. People don’t usually notices these waves until they strike. Tidal waves are created when an underwater earthquake or landslide cause major shifts at the bottom of the ocean. A Tidal wave is a series of big waves of different sizes. Some of these waves can be 15 minutes to one hour apart. The first waves are usually not the biggest, but they still get people’s attention!

Tidal waves move in all directions. They can have a wavelength of 100 to 150 miles and can move at speeds of as much as 500 miles per hour. Tidal waves are usually not noticed by sea captains because they are so long. These days, scientists call tidal waves Tsunamis.

Caught out by the tide!

Tarawa was one of the easternmost Pacific islands held by the Japanese, and the assault was the first amphibious assault in the Pacific during World War II. Sketchy tide data for the island suggested a tidal range of about seven feet. However, there were puzzling rumours of periods when the tides on Tarawa almost ceased, a condition local mariners called a dodging tide. Tarawa is a type example of an atoll, a flat-topped submarine mountain capped by coral. Most atolls, like Tarawa, have a wide shallow lagoon ringed by low coral islands. The only island of consequence at Tarawa was one with an airfield. The plan was for Allied ships to stand offshore in deep water and send landing craft into the lagoon. The landing craft would go as far in as possible and discharge troops.

The invasion was set for November 20, 1943 when tide conditions were expected to be favourable. At low tide in the early morning, the bombardment would begin. As the tide rose and water levels in the lagoon reached 1.5 meters (five feet), landing craft would head ashore and by noon, at high tide, heavier craft could come ashore bringing tanks and supplies. This isn’t the sort of thing you can call off and reschedule if things go wrong, as they did. Once an attack is under way, the enemy knows your intentions. Any delay merely gives the enemy time to reinforce or escape.

Unfortunately, the rumours of almost-tideless periods at Tarawa were true. November 20 was near last-quarter moon, resulting in a neap tide. Military planners knew about the risks of neap tide but did not realize the moon was unusually far from earth as well, weakening its tidal effects even more. Also, the Earth was only seven weeks from perihelion, meaning solar tides were unusually strong as well. Landing craft hit bottom hundreds of meters offshore and the Marines had to wade ashore under heavy fire. Once ashore, they had to fight without assistance, because supply ships could not come in. For 48 hours, the tidal range was only 60 centimetres (two feet), and it was four days before the tidal range increased to normal. 1027 American soldiers were killed and 2292 wounded in the battle.

Tidal Bores

USA - Alaska

The Turnagain Arm is a late Holocene fjord in filled with intertidal sediment. Located in the lower arm of the Cook Inlet, running east from Anchorage, the Arm has a majestic backdrop with the glaciated peaks of the Chugach Range close to its shores. At its mouth the Arm is around 10 miles wide and narrows to almost nothing over its 40 mile course. The tidal bore enters the narrowing Arm as a small wall of white water far out in the channels below Beluga Point. Much of its passage continues as white water over the shallow multiple channels. Beyond Bird Point, the bore runs into deeper water and takes on dynamic form with a spilling head wave and trailing undular swells.

Located at latitude 61 degrees north, the climate is cold, and ice sheets cover the Arm through winter. In summer, the silty, glacier fed, salt water only reaches a maximum of 7.5°C! The Arm is also home to a large array of wildlife and marine life. The changing seasons see the ebb and flow of Red Salmon, Hooligan and Beluga Whales as well as the mighty tidal bore.

UK - Severn Bore

Nestled in the heart of rural Gloucestershire, the River Severn exhibits a tidal bore over a distance of around 25 miles. The bore can first be sighted in the estuary channels below Awre (15 miles south of Gloucester). It then weaves its way through the channels around the magnificent horseshoe bend to be forced into the river above Longney Crib. From here it travels with discernible regularity up past Gloucester only to reach a sudden and silent end as it collides with Maisemore Weir.

Enshrouded in myth, history and legend, the bore has been both the destroyer and the saviour of the local inhabitants. Potent Sabrina, the Celtic goddess of the Severn, would stir up the river with her fury and anger, then ride the wild turbulent waters against the natural river flow. The majesty of the wave is more than complemented by the scenery that surrounds it. Livestock graze in the adjoining fields and the banks are adorned with colours that herald the changing of the seasons.

In winter the morning air is raw and the water is icy cold. On long summer nights, the river runs low and the passage of the bore occurs with the setting sun.

South America - the Amazon

The Amazon Basin has over a thousand known sources emptying into its main river and hourly pours more than 500 million cubic metres of water into the Atlantic (more than all the rivers of Europe combined). The total drainage area exceeds 2.5 million square miles, nearly half of South America. The many tributaries and estuaries of the Amazon vary dramatically in size, shape and especially colour. Sharp contrasts occur at the meeting of rivers: muddy browns, crystal blues, and the jet black of the Rio Negro.

With the dry season drawing to a close, and the full moon setting in the west, a great roar, poroc-poroc in the native Tupi Indian dialect, can be heard throughout the Amazon's mouths. With the rivers at an absolute minimum, it is not surprising that the vast Atlantic tides hurl the waters straight back with destructive and devastating fury.

The Pororoca has been sighted throughout the basin, from the tiny village of Sao Domingos do Capim in Para state, to the feared monster of the Rio Araguari in Amapa state's jungle depths. Amapa's capital, Macapa, lies on the Amazon's shore, south west of the expansive Canal do Norte, where the width of the pororoca extends to 16km. From this port boats are the only access to the remote channels around Ilha Mexicana and Ilha Caviana. The pororoca has even been sighted over 200km inland on the small Amazon tributary, the Rio Guajara.

With a maze of river channels, a diverse array of deadly creatures, and bank debris hurled up river in excess of 20mph, the concept of hunting down the pororoca is a truly phenomenal prospect.

France

The seventy kilometre long Gironde Estuary is formed by the confluence of the Dordogne and Garonne rivers 23km north of Bordeaux. Located between the Médoc and the Cotes vineyards, the estuary is the great artery of the Bordeaux wine region. Many tranquil villages line its banks, where life passes slowly in a relaxed french ambiance.

But for four or five days around the new or full moon the peace of the river is disturbed. For the large spring tides herald the coming of the Mascaret. Over its length the estuary narrows from around eleven to three kilometres, and before reaching the fork at Bayon a wave is visible at the head of the incoming tide. In fact the bore can be sighted earlier from the rural town of Cotes de Blaye with its overlooking citadel.

The mascaret continues its course up the Garonne breaking as fast barrelling waves in certain short sections finally dying out around Cadillac.

On the Dordogne the mascaret passes through a long stretch of meandering river. On one long horseshore-like bend the river passes the ports of St. Pardon and Vayres. It is here, as the early workers start about their day, that the bore riders congregate to ride the mascaret.

China

Jaws of the dragon, surfing the Qiantang.

The Chinese call it the Silver Dragon, and it is the largest tidal bore in the world. The Guinness Book of Records states, ‘at spring tides the wave attains a height of 7.5 m and a speed of 24-27 km/h.’ In the twelfth and thirteenth centuries, suicidal surfers would ride the bore on small planks of wood, in an attempt to placate the dragon’s wrath. It has wreaked havoc in the country side, killing many a thousand. It was only in 1988 that the Chinese finally permitted strangers on the Qiantang when the dragon roared.

The Asian tsunami of 2004

One of the world’s worst natural disasters in recent history. The chain reaction that set off enormous, deadly tsunami waves that struck seven nations in Asia and one in Africa started kilometres beneath the ocean floor off the tip of the Indonesian island of Sumatra. Geologic plates pressing against each other slipped violently in magnitude 9.0 on the Richter scale, creating a bulge on the sea bottom as high as 10 metres and as long as 1200 kilometres.

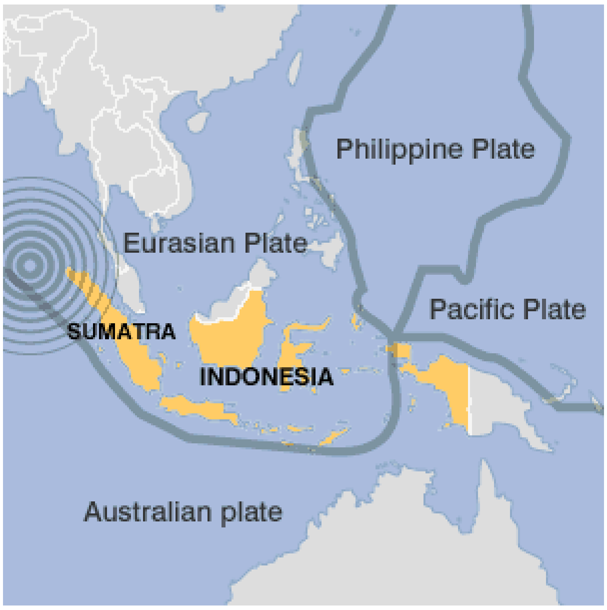
Imagine moving an enormous paddle at the bottom of the sea, a big column of water has moved, billions of tons, an enormous disturbance. Moving at about 800kph, the waves probably took about two hours to reach Sri Lanka, where the human toll has been horrific. But because tsunamis rarely occur in the Indian Ocean, there is no system in place to warn countries about to be hit, unlike the nations in the Pacific.

Circa One hundred and fifty thousands died in the tidal waves in India, Indonesia, Sri Lanka, Thailand, Malaysia and Bangladesh. Waves reached Somalia in Africa and even Rockingham, a beach south of Perth.

The underwater earthquake, which the US Geological Survey put at magnitude 9.0, is the biggest since 1964, when a 9.2-magnitude temblor struck Alaska.

The planet is vibrated from the quake. It could be likened in its power to a million atomic bombs the size of those dropped on Japan in World War II, the shaking was so powerful it even disturbed the Earth’s rotation.

There were at least a half-dozen powerful aftershocks, one of magnitude 7.3. The quake occurred at a spot where two massive geological plates press against one another with enormous force.
The Indian Ocean plate is gradually being forced underneath Sumatra, which is part of the Eurasian plate, at approximately the speed at which a human fingernail grows.
This slipping doesn't occur smoothly. Rocks along the edge stick against one another and pent-up energy builds over hundreds of years.
It's almost like stretching an elastic band, and then when the strength of the rock isn't sufficient to withstand the stress, then all along the fault line the rocks will move.
The quake probably occurred about 10km beneath the ocean floor, causing the huge, step-like protrusion on the sea bed and the resulting tsunami. As the waves move across deep areas of the ocean, they may be almost undetectable on the surface, swells of about a metre or less.
But when they near land, and the sea grows more shallow, the huge volumes of water are forced to the surface and the waves get higher and higher. On the beach itself, the wave can be as much as 30 metres high.
Indonesia is well-known as a major quake centre, sitting along a series of fault lines dubbed the "Ring of Fire". But scientists are unable to predict where and when quakes will strike with any precision. The force of the earthquake shook unusually far afield, causing buildings to sway hundreds of kilometres from the epicentre, from Singapore to the city of Chiang Mai in northern Thailand, and in Bangladesh.

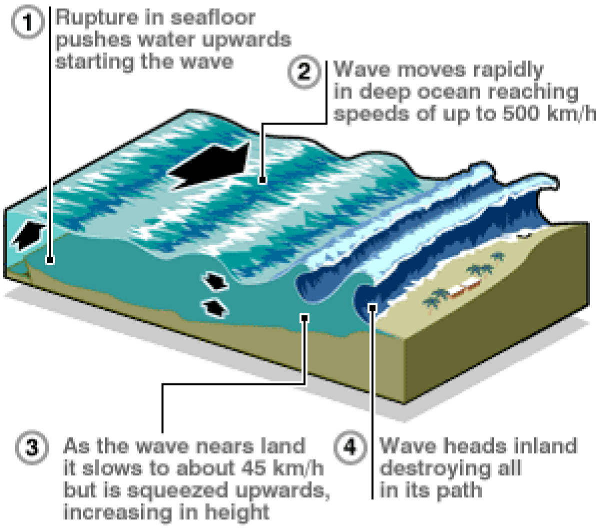


Violent rupture

The quake occurred close to the island of Sumatra.

Two tectonic plates, the Australian and Eurasian plates, meet just off Sumatra's south-west coast, grinding together and sending periodic seismic tremors through the region.

At 0759 (0059 GMT) a violent rupture occurred on the sea floor along a fault about 1,000km long.



Deadly wave

All along the rupture the seafloor was shunted vertically by about 10 metres.

This movement displaced hundreds of cubic kilometres of the overlaying water, generating a massive tsunami, or sea surge.

The wave then fanned out across the Indian Ocean at enormous speed.

Area affected

The 9 magnitude quake, which was the strongest in the world for at least 40 years, wrought havoc across the whole region.

Walls of water, tens of metres high, slammed into coastal areas thousands of miles apart.

Surging seas and floods were reported as far away as east Africa.

Scale of devastation

Millions of people were affected. Whole communities wiped out, and many of the survivors left homeless.

Thousands of unidentified bodies have had to be buried or burned.

The UN mobilised one of the world's largest relief operations.

Natural disasters - Key points

On average, an earthquake strikes the British Isles every four days

10% of the world's population live under threat from the 1,511 active volcanoes

There are more tornadoes per square mile each year in Britain than the USA

In Britain, five million people in two million homes live in flood prone areas

Colossal tsunami waves travel across oceans at speeds of up to 500mph (800kmh). Waves hitting coastlines have shifted 20-tonne rocks hundreds of metres inland

Droughts starve the land of nourishment, replacing them with mineral salts

Could natural disasters devastate Britain?

If the volcano on La Palma in the Canaries explodes, a 500m high mega-tsunami could engulf low-lying parts of the UK

Though some scientists believe it will happen, it's unlikely for the next few thousand years

In 1995, a hurricane doubled back from the Caribbean and hit Britain

This UK storm was only the remnants of a hurricane. In order to retain its strength, a hurricane must remain over warm water of 26.5C or above

North-west Wales is one of the most seismically active places in the whole UK. In 1984, a quake registered 5.4 on the Richter scale. Another could hit any day now. An earthquake of this magnitude rarely causes severe damage. Quakes above 5 are exceptional in the UK, and there is no proof that another is due soon

Big waves

Following the world's biggest earthquake off the coast of Chile in 1960, a series of waves created havoc around the Pacific Rim. It caused 56 deaths in Hawaii, 32 deaths in the Philippines, and 138 deaths in Japan - 10,000 miles (16,000km) away.

A tsunami (pronounced soo-nam-ee) is a chain of fast moving waves caused by sudden trauma in the ocean. They can be generated by earthquakes, volcanic eruptions, or even the impact of meteorites. Tsunamis are what we used to call tidal waves.They are most common around the edge of the Pacific, where more than half of the world's volcanoes are found. These seismic surges can assault coastlines, often with little or no warning. Rocks weighing as much as 20 metric tonnes have been plucked from sea walls and carried 180m inland.

Tsunamis aren't like wind-generated waves that rhythmically roll onto a beach. A tsunami can have a wavelength (ie distance between wave crests) in excess of 60 miles (100km) and there may be an hour between them. They travel at great speeds across an ocean with hardly any energy losses and are barely noticeable out at sea.Over the deep Pacific Ocean, a tsunami travels at about 500mph (800kph). If an earthquake happened in Los Angeles, a tsunami could hit Tokyo quicker than you could fly between the cities by jet.As a tsunami leaves the deep water of the open ocean and travels into the shallower water near the coast, it behaves like a normal wave - only with more muscle.Shallow water slows the tsunami and its height grows. Tsunamis batter the coast with tremendous amounts of energy. They can strip sand from beaches, tearing up trees, and even obliterating whole towns. Some have been known to reach as much as 30m above sea level.

Time bombs within the oceans

Scattered across the world's oceans are a handful of rare geological time-bombs. Once unleashed they create an extraordinary phenomenon, a gigantic tidal wave, far bigger than any normal tsunami, able to cross oceans and ravage countries on the other side of the world. Only recently have scientists realised the next episode is likely to begin at the Canary Islands, off North Africa, where a wall of water will one day be created which will race across the entire Atlantic ocean at the speed of a jet airliner to devastate the east coast of the United States. America will have been struck by a mega-tsunami.

Back in 1953 two geologists travelled to a remote bay in Alaska looking for oil. They gradually realised that in the past the bay had been struck by huge waves, and wondered what could have possibly caused them. Five years later, they got their answer. In 1958 there was a landslide, in which a towering cliff collapsed into the bay, creating a wave half a kilometre high, higher than any skyscraper on Earth. The true destructive potential of landslide-generated tsunami, which scientists named “Mega-tsunami”, suddenly began to be appreciated. If a modest-sized landslide in Alaska could create a wave of this size, what havoc could a really huge landslide cause?

Scientists now realise that the greatest danger comes from large volcanic islands, which are particularly prone to these massive landslides. Geologists began to look for evidence of past landslides on the sea bed, and what they saw astonished them. The sea floor around Hawaii, for instance, was covered with the remains of millions of years’ worth of ancient landslides, colossal in size.

But huge landslides and the mega-tsunami that they cause are extremely rare - the last one happened 4,000 years ago on the island of Réunion. The growing concern is that the ideal conditions for just such a landslide - and consequent mega-tsunami - now exist on the island of La Palma in the Canaries. In 1949 the southern volcano on the island erupted. During the eruption an enormous crack appeared across one side of the volcano, as the western half slipped a few metres towards the Atlantic before stopping in its tracks. Although the volcano presents no danger while it is quiescent, scientists believe the western flank will give way completely during some future eruption on the summit of the volcano. In other words, any time in the next few thousand years a huge section of southern La Palma, weighing 500 thousand million tonnes, will fall into the Atlantic ocean.

What will happen when the volcano on La Palma collapses? Scientists predict that it will generate a wave that will be almost inconceivably destructive, far bigger than anything ever witnessed in modern times. It will surge across the entire Atlantic in a matter of hours, engulfing the whole US east coast, sweeping away everything in its path up to 20km inland. Boston would be hit first, followed by New York, then all the way down the coast to Miami and the Caribbean.

Tidal Whirlpools and Maelstroms

Gulf of Corryvreckan Legends and Facts

Facts
A brief outline of how the 'whirlpool' works follows. 'Maelstrom' would be a better description.

The whole of the Sound of Jura is a tidal anomaly. The tide is low in Lochgilphead when the tide is high in Crinan. It is absolutely diametrically opposed.
This is curious when only six miles separate the two, on land at least. However, the Mull of Kintyre, a peninsula over sixty miles long, forms a wall opposite the island chain formed by Islay, Jura, Scarba, Lunga and Rubha Fiola.
As the tide ebbs south past the gaps between these islands, it sucks the tide up the Sound of Jura, flooding and rising north. It then flows west, out through the Corryvreckan, The Grey Dog and north through Fladda.

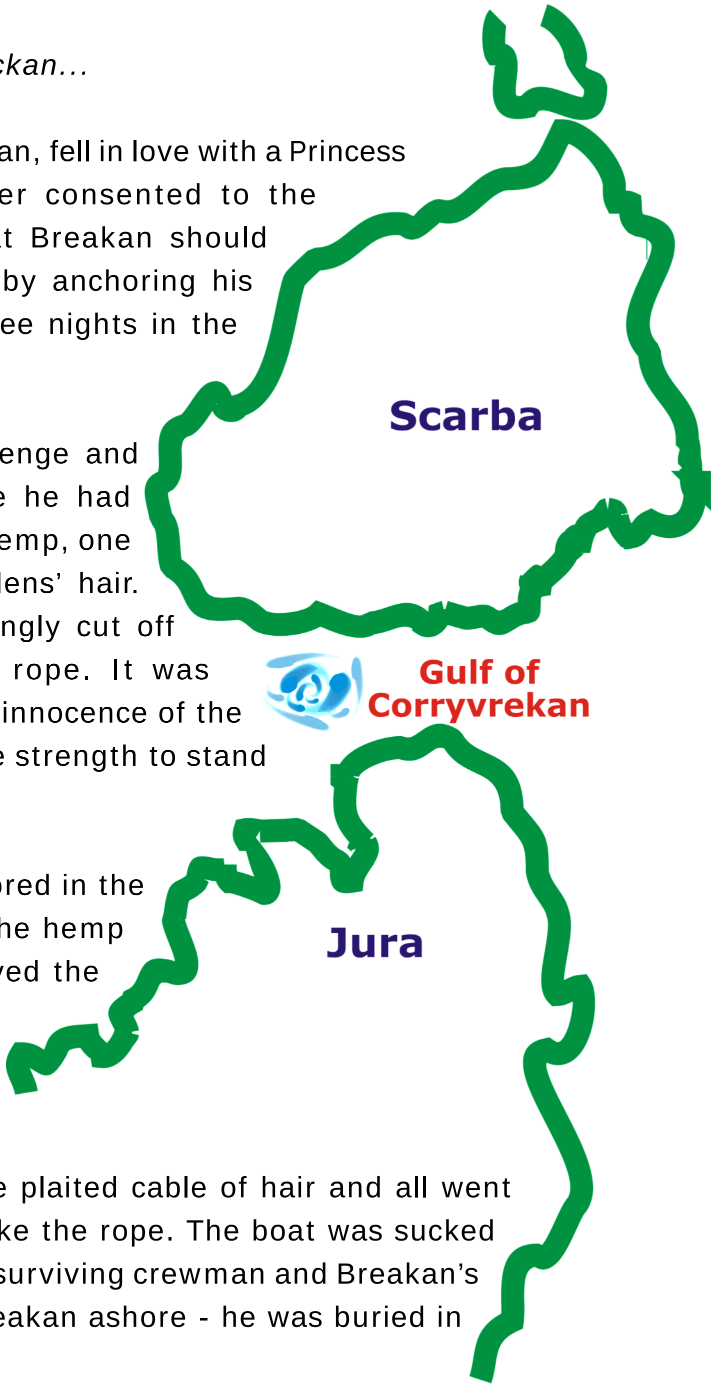
The maelstrom in the Corryvreckan works differently when the tide is ebbing from when it is flooding.

On the ebb, water is flowing in relatively undisturbed from the open sea. On the flood, water has flowed up the Sound of Jura and has been agitated by the topography of the sea-bed.

There are innumerable humps and holes and reefs in the Sound and these create terrific tidal flows, upthrusts and eddies all over the place until finally in the Gulf there is a huge hole down to 219 metres before being confronted by a pinnacle of rock off the Scarba shore which rises to 29 metres from the surface.

Thus building, in gale force conditions, standing waves that can be 8, 10 or 15 feet high. A truly awesome sight!
When the wind is from the South East or from N or E of North, then the Gulf is in the lee and it tends to be less rough - one can see the pure tidal turbulence. The relative state of Springs to Neap tides also affects the strength of the flows and hence turbulence. So as you can imagine there

are many, many factors which affect the performance and so one can never be entirely sure how it will be behaving before one gets there.



The Legend of the Corryvreckan...

A Scandinavian Prince, Breakan, fell in love with a Princess of the Island, whose father consented to the marriage, on condition that Breakan should show his skill and courage by anchoring his boat for three days and three nights in the whirlpool.

Breakan accepted the challenge and returned to Norway, where he had three cables made.. one of hemp, one of wool and one from maidens' hair. The women of Norway willingly cut off their hair and plaited the rope. It was believed that the purity and innocence of the maidens would give the rope strength to stand the strain.

Breakan returned and anchored in the whirlpool. On the first day the hemp rope parted, but they survived the night. On the second day, the woollen rope parted in a strong wind, but they survived the night again.
On the last day they set the plaited cable of hair and all went well until a gale of wind broke the rope. The boat was sucked under by the currents and a surviving crewman and Breakan's dog dragged the body of Breakan ashore - he was buried in the King's Cave.

When the crewman finally made it home again and told of Breakan's fate, one of the young Norwegian ladies was consumed with guilt, as she was not as pure as she had made out - it had been her hair which weakened the rope.

Acknowledgements
Gemini Cruises & Water Taxi
Kilmahumaig, Crinan, Lochgilphead, Argyll, Scotland PA31 8SW
Tel: +44 (0) 1546 830238 Fax: +44 (0) 1546 830238

Answers to frequently asked questions about tides

What is a tide?

A tide is the regular and predictable movement of water caused by astronomical phenomena - the way the earth, moon and sun move in relation to each other and the force of gravity. Movement of water caused by meteorological effects (for example winds and atmospheric pressure changes) are called surges. (A large positive storm surge can add a few metres to the predicted water level.)

How far ahead can the tide be predicted?

Since the tide is caused by the astronomy of the earth-moon-sun system the tides can also be predicted well into the future.

When trying to predict well into the future, we have to take into account the rise in global sea level. The further into the future we try and predict, the more significant this effect can become.

What causes tides?

Tides are caused by the gravitational pull of the earth-moon-sun system. There are two bulges of water - one towards the moon and another on the opposite side The rise and fall in sea-level is caused by the earth rotating on its axis underneath these bulges of water. There are two tides a day because it passes under two bulges for each rotation (24 hours).

If gravity is always pulling towards the moon, why is it that all the water is not just pulled towards it?

There are two forces acting: gravity towards the moon and a rotational force away from the moon. On the opposite side the gravity towards the moon is less and is counteracted by this rotational force pushing away from the moon

Why are the tides not the same all round the coast?

If you were in the middle of the ocean there would be imperceptible tide difference between one point and another. The shape of the land (topography) and depth of water (bathymetry) make an enormous difference. Every location has a unique pattern that can cause considerable variation. The coastline length around mainland Great Britain is 11 072.76 miles, every part of it having individual characteristics that affect the tide.

How often do high tides occur?

In our European area approximately every 12 hours 25 minutes.

Why not exactly 12 hours?
Remember the moon is also rotating, so the earth has to rotate for an extra 25 minutes to be under the same point.

Are there always two high tides a day?
No. Although most places in Britain do. Some places like Southampton have double high tides and stands (semi-diurnal). This is caused by the shape of the coastline and the bathymetry (sea depth). In some parts of the world there is only one high and one low water each day (diurnal).

What are spring tides and neap tides?
When the earth, moon and sun are in line (during new and full moon), we have spring tides, when the gravitational pull of the sun and moon are lined up. The lunar tide and the solar tide are reinforcing each other - leading to higher and lower tides.
When the earth, moon and sun form a right angle (at 90°) the gravitational pull counters one another - producing lower high waters and higher low water, these are neap tides, occurring approximately 7 days after spring tides.

Where are the highest tides in the world?
The Bay of Fundy, Canada has an average spring tidal range of 12.9 m. The second largest tides in the world occur at Avonmouth in the Bristol Channel where the average spring range is 12.3 m.

Do the tides follow a repeated pattern?
No, the cycle takes 18.6 years, - but the pattern never actually repeats itself.

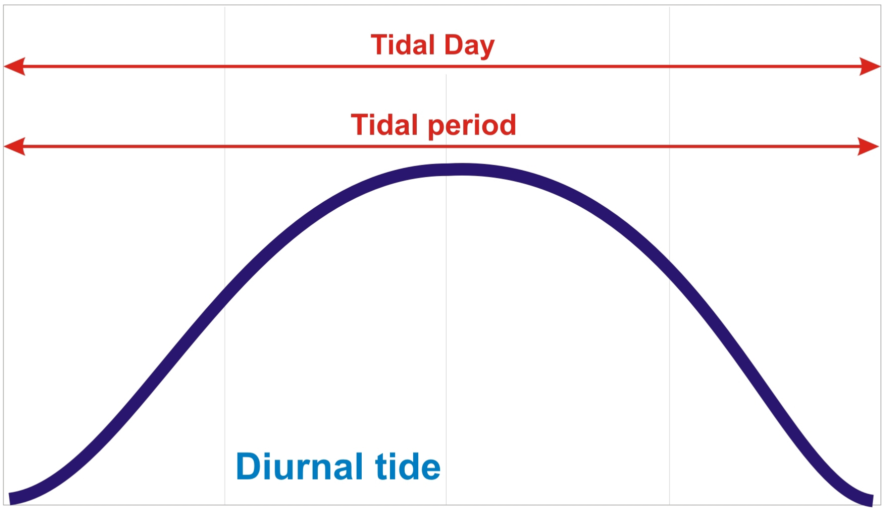
When during a year can we expect to find the largest tides?
A day or two after the full or new moon nearest to the equinoxes.
1997 was a significant year, 2015 will also have large tides. 3182 will also produce high tides, but probably not worth the wait.

Do other planets have any affect on the tides?
All planets have an affect but it is their distance that has a bearing. The nearest to earth Venus is still more than 100 times further away than the moon. The tidal force is approximately 0.000054 times that of the moon. Next is Jupiter, where the tidal force is 0.000005 times that of the moon. Thus, the effect of the planets is negligible, the answer is no.

Types of tides

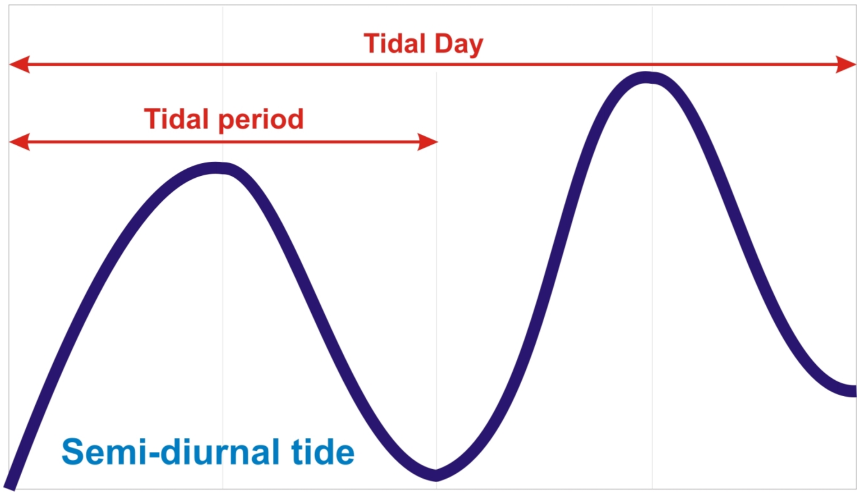
The angle of the moon and sun in relation to the earth's surface give rise to three different types of tides.

The geometric relationship of the sun and moon (declination) in relation to the earth result in different types of tides. In South East Asia and parts of the Northern Gulf of Mexico there is only one high and low water per day, this is known as diurnal tides.



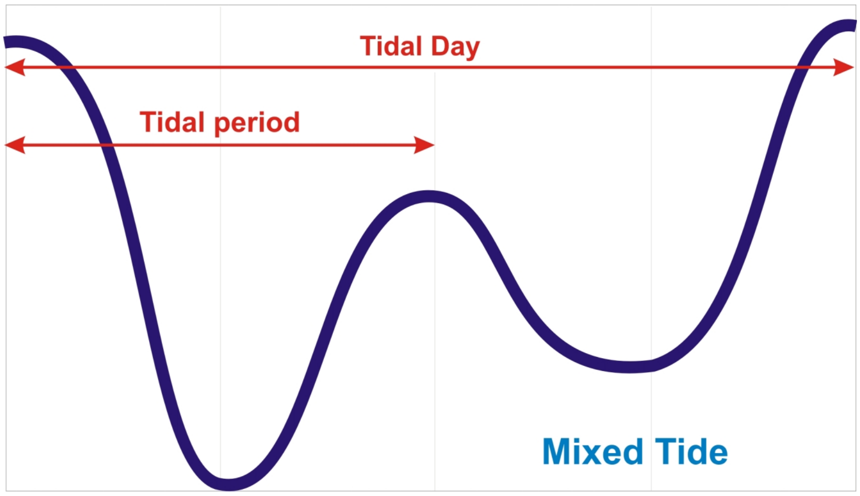
The Gulf of Mexico and Southeast Asia have one high water and one low water per day. These tides are called diurnal tides

The Atlantic coasts of the United States and Europe have two high and low waters per day, these are known as semi-diurnal tides.



On the Atlantic coasts of the USA and Europe there are two high waters and two low waters per day, these are called semi-diurnal tides.

Additionally many parts of the world experience mixed tides where high and low water stands differ appreciably. These tides can be found around the west coast of Canada and the united states.

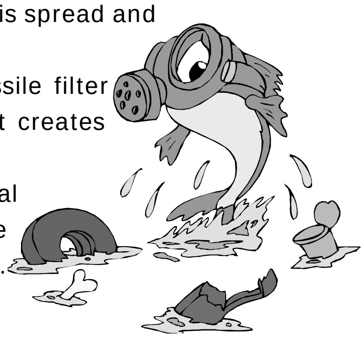


Mixed tides - the tides around the West Coast of Canada and America are of this type.

What are the effects of tides on the environment?

How would the world differ without tides? The answer to this is relatively easy to establish. If we look at the Mediterranean Sea, which is relative small and enclosed resulting in negligible tidal movement, the tidal range is less than 20cm; we can observe that life is quite pleasant. For the sailor, no tidal gates, no overfalls and no wind against tide horror etc. There is a good underwater environment supporting a high number of species, fishing is satisfactory but it does not support some of the high volumes as can be seen in tidal areas. The following will not occur without tides:

- Dunes cannot form, tides reveal sand to the wind that blows into dunes
- A variety of organisms evolve in the rocky shores which are both exposed to the air and covered by water, increasing the bio diversity of the coast, e.g., limpets barnacles, oysters etc.
- Tides create large areas for specialist organisms within harbours and bays, e.g., sand and mud flats, mangroves etc.
- Tides create currents that mix water so that plankton is spread and bottom nutrients resurface.
- Tides create currents that transport plankton to sessile filter feeders such as clams, sponges, sea squires, etc. It creates very rich habitats where currents pass.
- Tides create currents that transport and mix coastal sediment. Without them, the coast would be more sensitive to sewage disposal and runoff from the land.



Basically it would support fewer people.

Tidal Streams

Tidal streams relate to the movement of water in a horizontal direction, tide is a movement in the vertical direction, the cause of this horizontal movement is due to the same causes as the tide. If you imagine the sea on the surface of the globe where it is lower in one part than another, it will have the effect of drawing water in thus causing horizontal movement. The tidal stream associated with a rising tide is referred to as the flood stream, the falling tide is referred to as the ebb stream. Slack water, when there is no or little tidal stream, is the period before the stream changes direction. It is important not to confuse the two terms tide (vertical movement) and tidal stream (horizontal movement). Tidal streams can be analysed and predicted in much the same ways as tides. Using the time lag between different levels to calculate horizontal movement. It should be noted that the slack period does not necessarily occur at High or low water, on some occasions the tidal stream could be quite strong during the period of high and low water.

The speed and direction of tidal streams are affected by the topography (shape) of the land and bathymetry (depth of the sea). Two examples of how the topography affects tidal streams are:

1. where there is a small sea lough connected to the sea with a large mouth to the lough
2. where there is a large sea lough connected to the sea with a small mouth to the lough.

In the first example the level of the water inside and outside the lough will remain the same and the velocity (speed) of the stream will be at its greatest when the height of the tides is most rapidly changing, normally half way between high and low water.

In the second example the level inside and outside the lough will not be the same as the restriction on the mouth of the lough holds water back. Again, depending on the topography, there could be a difference of three hours between high water inside the lough and outside it. In these circumstances the tidal stream will be flowing at its strongest velocity at high and low water, slack water will occur at mid tide of the sea outside the lough.

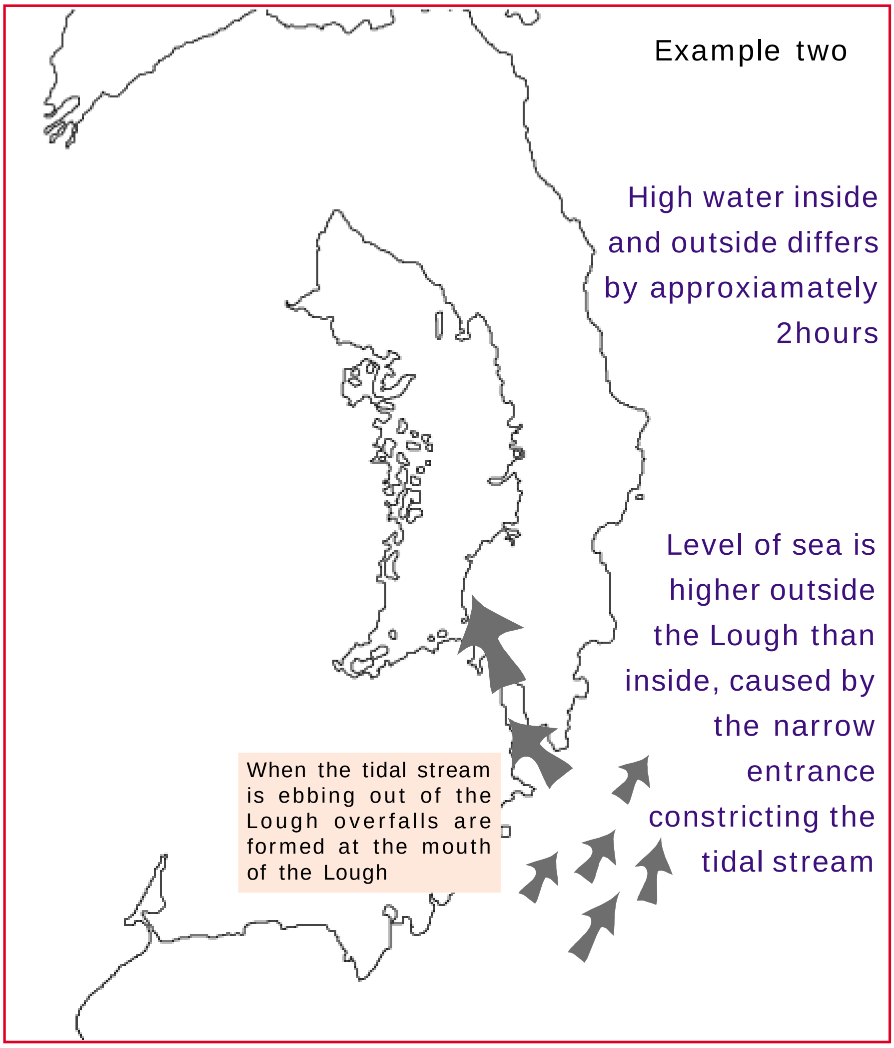
Belfield Software - www.tideplotter.co.uk - email:general@tideplotter.co.uk

Rule of Twelfths

Assuming a period of approximately 6 hours between LW and HW with slack water around High and Low water the “Rule of Twelfths” describes the varying velocity of the tide throughout its cycle.

- *1st hour after LW, 1 twelfth of the total water displaced flows in*
- *2nd hour after LW, 2 twelfths of the total water displaced flows in.*
- *3rd hour after, 3 twelfths of the total water displaced flows in.*
- *4rd hour after, again 3 twelfths of the total water displaced flows in.*
- *5th hour after, 2 twelfths of the total water flows in.*
- *6th hour after, 1 twelfths flows in.*

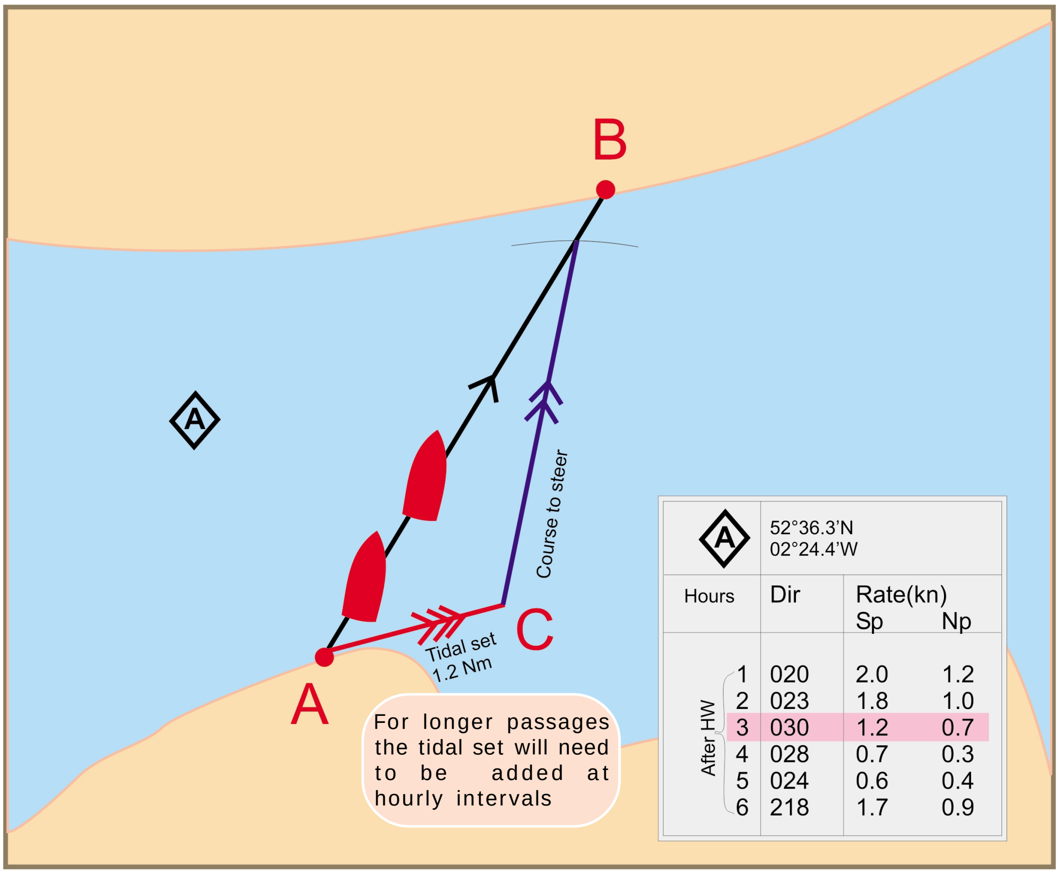
Therefore, the fastest streams take place during the 3rd and 4th hour after slack water (HW or LW) when the largest amount of water travels (six twelfths or one half of the total water displaced). The same pattern is true for the tide going out from HW to LW.



Tidal Streams and Passage Planning

To determine a course from point A to point B we need to ascertain the following information from the chart:

- The nearest tidal diamond, in this case diamond A
- The grid on the chart that indicates the direction and speed of the tidal stream at diamond A

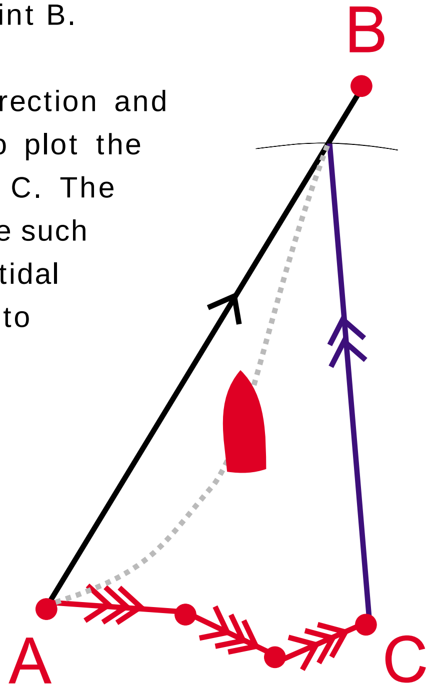


Hours		Dir	Rate(kn) Sp	Np
After HW	1	020	2.0	1.2
	2	023	1.8	1.0
	3	030	1.2	0.7
	4	028	0.7	0.3
	5	024	0.6	0.4
	6	218	1.7	0.9

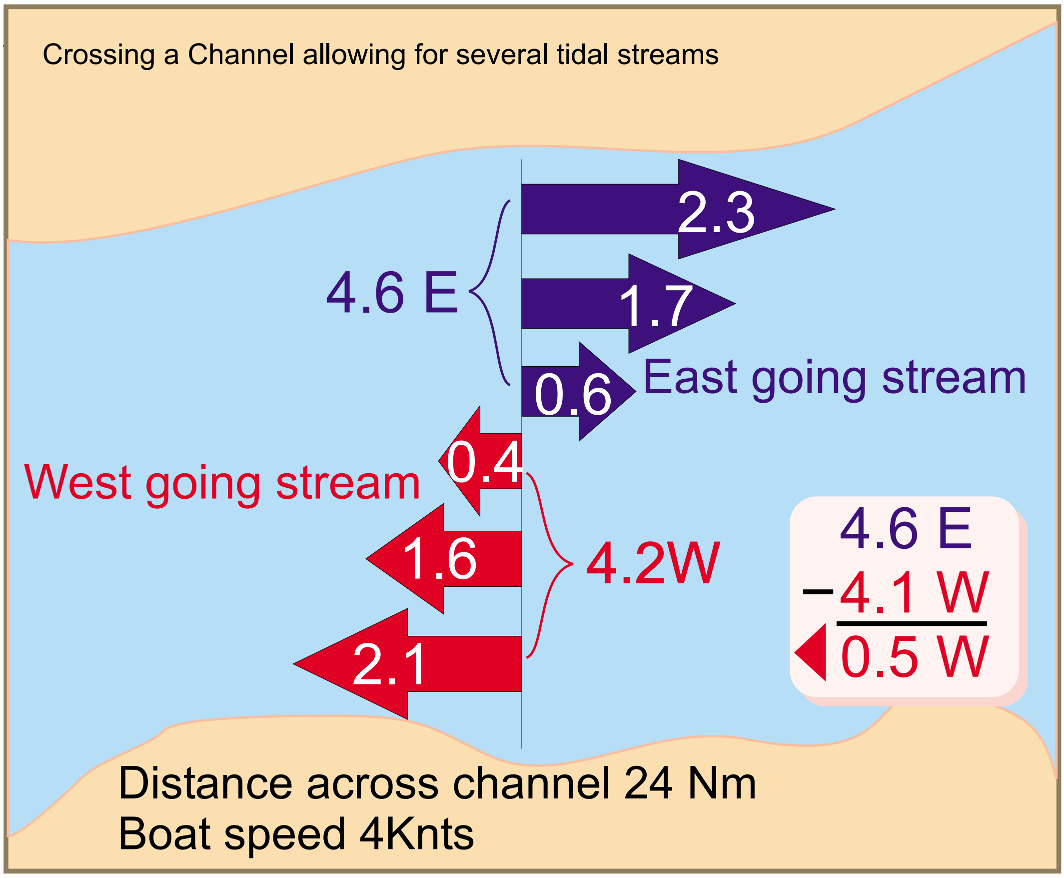
- Determine the time in relation to HW in this case 3 hrs after HW
- Transfer a line of true bearing 30 degrees from point A to point C (tidal set direction)
- As it is a spring tide measure 1.2Nm along this line. If it was a neap tide you would measure 0.7 Nm and if it was between the two you would need to interpolate the rate accordingly.
- As this example is for one hour, measure your speed 5 knots x 1hour (to give the distance in Nm,) along the line from the end of the tidal set line C to cut the line A to B, this line gives the course to steer. Remember that it is a true bearing and you will need to adjust for variation, deviation and leeway.
- Over a passage of several hours you would need to work out the tidal set for each hour and strike off the appropriate distance.

Setting a course from point A to point B.

When the tidal stream changes direction and speed each hour it is necessary to plot the tidal vectors for each hour, A to C. The diagram on the right illustrates three such hourly changes. From the last of the tidal vectors at point C it is necessary to strike off the distance travelled (speed x time) to cross the line A to B to establish the course to steer

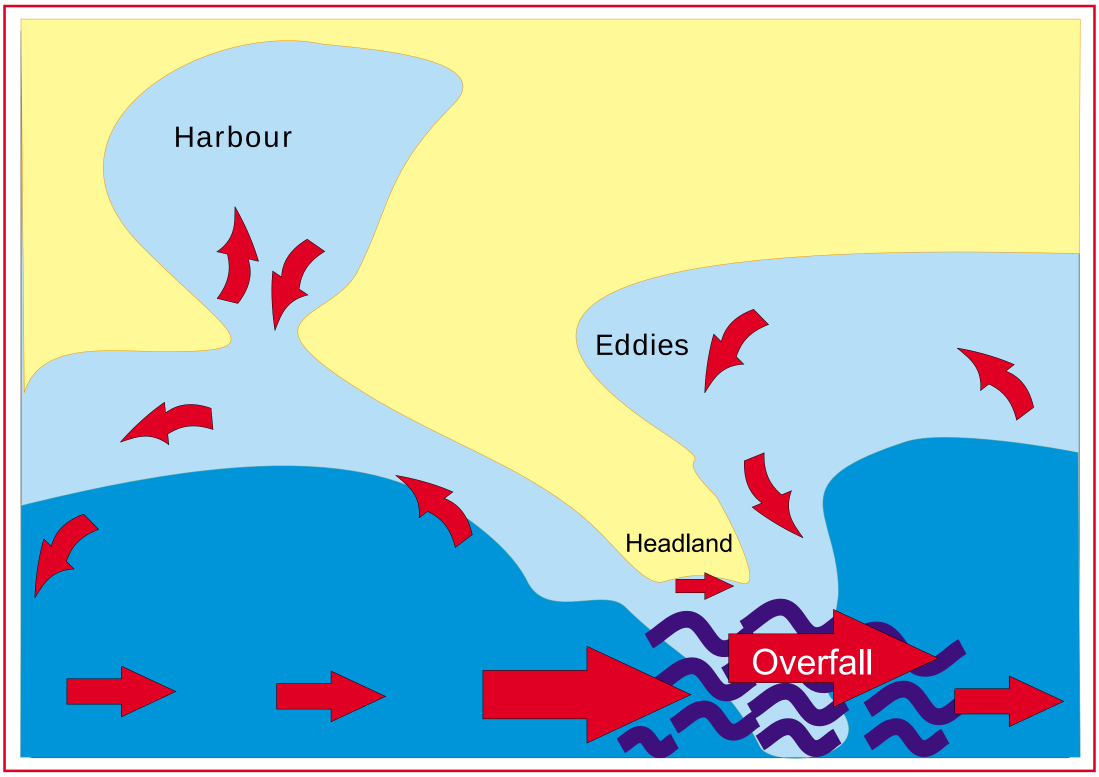


When crossing a channel the tidal stream often runs in one direction for the flood and the other for the ebb. It is possible to minimise the variation to your course caused by the tide by choosing a start time when there are similar amounts of flood and ebb tide.



Tidal Streams inshore anomalies

Where there tends to be an inconsistent shape to the sea bed and sharp variations in the shape of the coast, the tidal stream behaves in a widely varying manner. From the diagram below you can see how stream



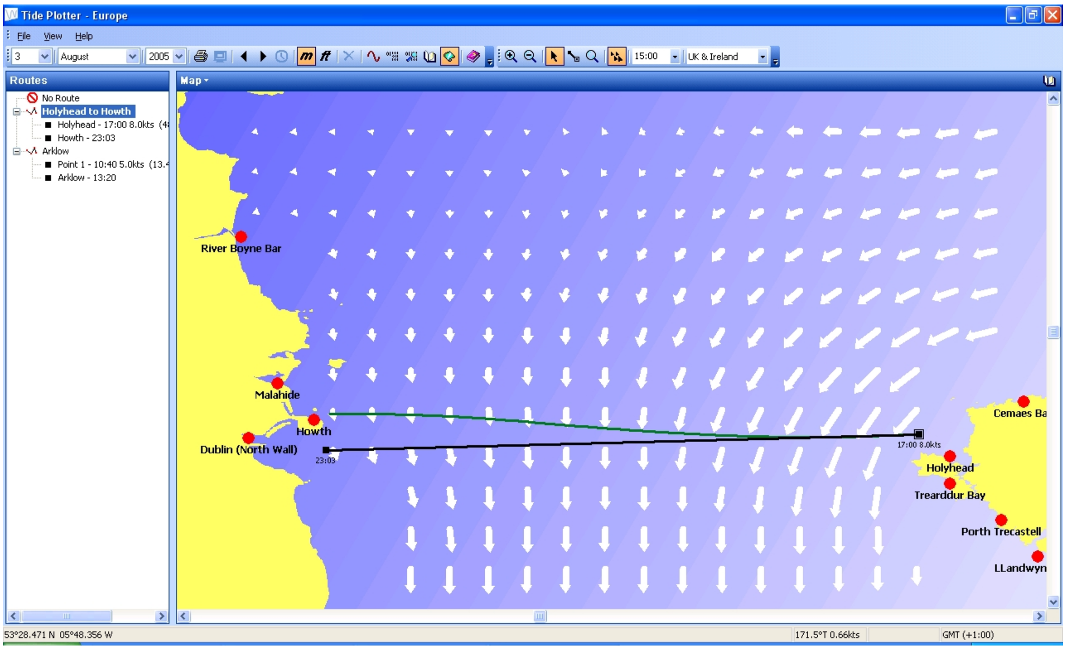
reversals, (eddies), overfalls and strong and slack streams are formed. Overfalls are formed when the stream in deeper water meets a shallower ledge and the flow is constricted; a jutting headland can also contribute to this effect. The result is a confused sea with standing waves sometimes dangerous for passage making. Passage is often best planned for slack water. Quite often there is a slacker flow close to the headland and can be used to advantage when passage making. Local knowledge and the good use of pilots are necessary.

As the depth inshore decreases the stream will usually slacken and the shape of the coast can cause stream reversal, eddies. This can be used to advantage if trying to avoid a strong contra stream.

The narrow harbour entrance will have the stream going inwards on the flood tide and outwards on the ebb tide. The strength of the stream can often increase where the water is forced through a constriction.

Tidal Streams using computational method

Calculating tidal vectors has been made much easier using computers to calculate tidal streams and course to steer. This example of a program, TidePlotter.co.uk, calculates the vectors at two minute intervals and uses algorithms to claculate the tidal stream speed and bearing at two minute intervals. These sort to calculations would not be practical using a chart dividers and compass rose.



On the example above the passage is from Holyhead to Howth.

With just simple clicks on the map at Holyhead and then Howth a line is drawn between the two points. Immediately a green line indicates the tidal drift. To work out your course to steer it is just a simple matter of moving the destination point such that the tidal curve line finishes at the desired destination, Howth.

All the details of the passage are displayed on the left hand side of the screen: bearing, course to steer, start time and finish time based on your average speed.

In terms of planning it is an easy matter to change estimated speed, and/or start time to establish the most effective passage route to maximise the shortest passage distance and to see exactly the effect of the tide on your passage. The computer makes thousands of calculations that would not be possible on your chart table.

Wind and tide

The astronomical data used to predict tides is relatively reliable giving predictions many years in advance. The weather, however, can have a major impact on tides in anything other than average conditions. Strong winds, gales and storms, particularly over a long period of time and very high or low pressure can all create large differences from the astronomic prediction. For example, differences of 2.3 metres at low water have been recorded due to adverse weather conditions. Abnormal barometric pressure will affect the tide height whilst prolonged wind will cause variations in the timing of high and low water.

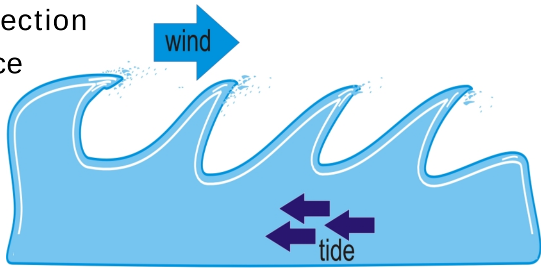
Tide predictions are based on an average barometric pressure of 34 millibars. Low pressure will tend to raise the sea level whilst high pressure will depress it. Changes of more than 0.3m in height are seldom caused by abnormal barometric pressure but this can be increased by the effect of strong winds and storm surges.

Strong wind can have a considerable impact on tide heights. Strong onshore winds particularly those of a prolonged nature will tend to pile up the water on the shore and increase the height. Offshore winds will have the opposite effect. Winds along the coast will build up waves called storm surges with the height being raised at the crest and lowered in the trough.

70 mph onshore winds from the Irish Sea give rise to higher than average tides

Wind against tide

The speed at which the wind travels over the surface of the sea determines the sea state, height of waves etc. If the wind speed is 20 knots and there is no current then the true speed of the wind over water is 20 knots. If the current is travelling at 4 knots and is going in the same direction as the wind then the speed of wind over the surface of the water is 16 knots, (wind speed – current). With the current going in the opposite direction to the direction of the wind the surface speed increases to 24 knots (wind speed + current). From this example you can determine that wind against tide can have a considerable effect in worsening the sea state. This example demonstrates a difference of 8 knots of wind over the surface of the water depending whether the tide is ebbing or flooding. Seas created in this wind tide adversarial state are shorter, taller and steeper, they can crest, break and lead to dangerous sea conditions.



South Stack Overfall with wind against tide conditions.
The combined effect of the overfall and wind against tide create standing waves and conditions that you would not want to be in. This overfall can extend five miles out to sea

Seismic Waves

Caused by underwater earthquakes. An Earthquake can set long waves which travel at great speeds, the danger from such a wave occurs as it reaches shallow water.

Where are heights measured from?

The levels used on charts and in tide predictions are taken from Chart Datum (CD). This is the lowest level that a tide is likely to go; this is normally the level of the Lowest Astronomical Tide (LAT). These levels are under average meteorological conditions.

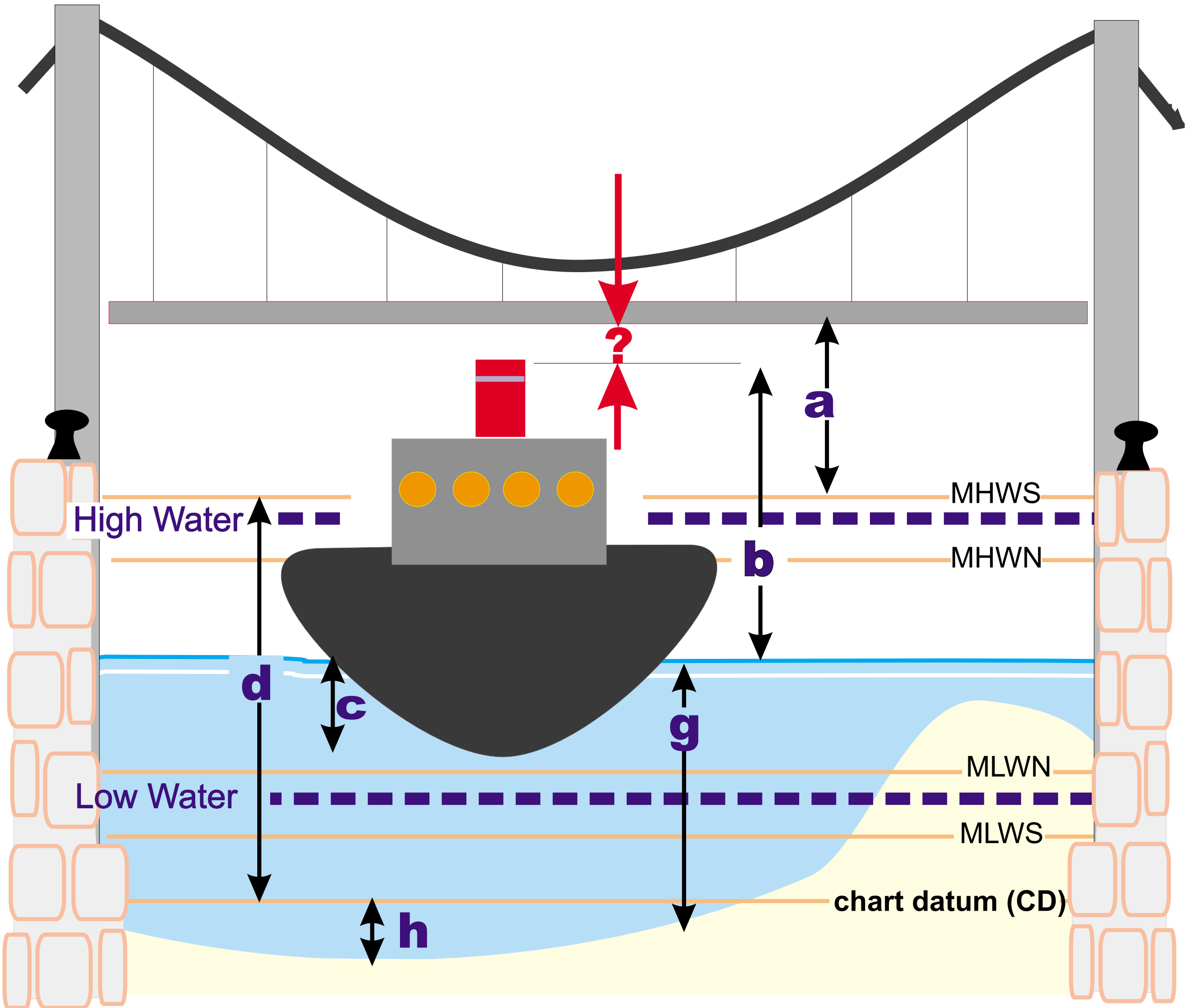
Tide levels

The following are definitions used for datums relating to tide heights:

LAT	Lowest astronomical tide, the lowest level the tide is likely to go to reach under normal meteorological conditions
CD	Chart datum is the zero for tide predictions, approximately equivalent to LAT
MLWS	Mean Low Water Spring. The mean level for the low water spring tide
MLWN	Mean Low Water Neaps. The mean level for the low water neap tide
MSL	Mean Sea Level. The mean level of the sea surface
MHWN	Mean High Water Neaps. The mean level for the high water neap tide.
MHWS	Mean High Water Springs. The mean level for the high water spring tide. This is also the datum level that height measurements are taken from.
HAT	Highest Astronomical Tide. The highest predicted level that the tide is likely to reach under normal meteorological conditions.

The following diagram illustrates how many of these datum levels are needed to be understood as the basis for calculations that will enable boats to pass safely around our tidal shores.

In this diagram there are various depths and heights that need to be known in order for the ship to be able to safely navigate under the bridge. The level of the water needs to be ascertained for the time that the ship will be under the bridge to establish depth and height clearances.



a =	charted height of bridge, taken from MHWS
b =	height above waterline
c =	draught, distance of water level to bottom of keel
d =	height of MHWS above chart datum (CD)
g =	depth of water taken from waterline
h =	charted depth
g - c =	depth under keel

Predicting tide heights and times

Having the ability to carry out the necessary calculations for predicting height and times of tides is essential, and yet is one of the most difficult parts of any navigation syllabus. In practice it is almost impossible to passage anywhere around our shores without having to plan when to cross the drying bar, enter marinas and locks, or, catch the tidal gate at just the right time. As has been outlined earlier in this book it is relatively straightforward to predict tide times and heights based on the available astronomical data, plus data produced from the hydrographic departments surveying our coasts. Our knowledge base, however, needs to extend further than the times and heights of the two high and low waters found in tide tables. At what time will the depth of water over the sandbank be at least 3.5 m to allow safe passage? At what time will the tide be at HW slack to allow safe passage through the Swellies? It is a rare occurrence to be able to go out for a day on tidal waters without pre-planning the times and heights of tides. Much of the raw data needed to make height and time calculations is available in Almanacs and the Admiralty Tide Tables. That data does, however, need to be manipulated to some tune to get the very specific and detailed information that we require in everyday practical situations. Given we have ascertained the HW and LW times at port A, how do we go about finding the times and heights midway between HW and LW at port B? The following pages outline examples of how to go about making detailed tidal calculations. There is no escaping the need for some knowledge in, either mathematics, or, applied geometry to calculate the specific tidal detail we might require. Interpolating between two different sets of data, using the calculator to do the same thing, or, just straight forward mental arithmetic, are the skills required. We can get help, the use of computers influence everything we do in life and there are computerised programs (tideplotter.co.uk) that take out much of the hard work out of the maths and provide results in a split second at the push of a button. But beware, as with all electronic aids relating to navigation there is a health warning, do not solely rely on them and have the knowledge to carry out the calculations yourself.

It is important to bear in mind that whatever method you use, they are only predictions and the real thing can vary from your theoretical calculation. Working in the very stable exam like conditions of a classroom are a million miles apart from working at the chart table on a small yacht being pitched around in a force 6. Spending inordinate periods of time getting the result to the nearest tenth of a metre might not be relevant or practicable on board.

Predicting times and heights of tides - standard and secondary ports

In reference books such as Almanacs, Admiralty Tide Tables (ATT) etc., ports are categorized by two main types:
Standard ports and Secondary ports.

Standard ports

These are ports of a more substantial nature where there is a likelihood of greater shipping traffic. Observations used for tide predictions are normally carried out over a longer period at standard ports than secondary ports. Observing and analysing changes are carried out over a period of at least one year and in practice more likely three years.

These ports are also used as the basis from which to add or subtract time and height differences to obtain the data for secondary ports.

You will find the times and heights of high and low water tabulated in Almanacs and the Admiralty Tide Tables, for every day of the year. It is important to note the time zone and adjust the time to real time if necessary. For example, the Admiralty Tide Tables use UTC / GMT for all times throughout the year, during the summer months you will need to add one hour to convert to BST.

Secondary Ports

Secondary does not mean of less value or importance and to many tidal users they are just as significant, if not more so, than the Standard port. Predicting times and heights at these ports can be established by adding or subtracting time and height differences from a standard port, or by using harmonic constants and the Simplified Harmonic Method of Tidal Prediction. When adding and subtracting differences from the standard port the data is variable in quality, modern revisions for this data are based on one month observations.
Using the simplified Harmonic method is a better method of establishing secondary port heights and times but is a very complicated and heavy on mathematics. Consequently it is little used in practice unless incorporated into a computer model.

To obtain high and low water times and heights for secondary ports it is necessary to add or subtract times and heights from the most appropriate standard port. It is important to note that this port is the one with the most similar characteristics and is not necessarily the nearest. The most appropriate port is clearly identified in the Almanac or Admiralty Tide Table. The time differences given are those likely to occur under average weather conditions and whilst given to the nearest minute it cannot be assumed that in reality it will be that accurate.

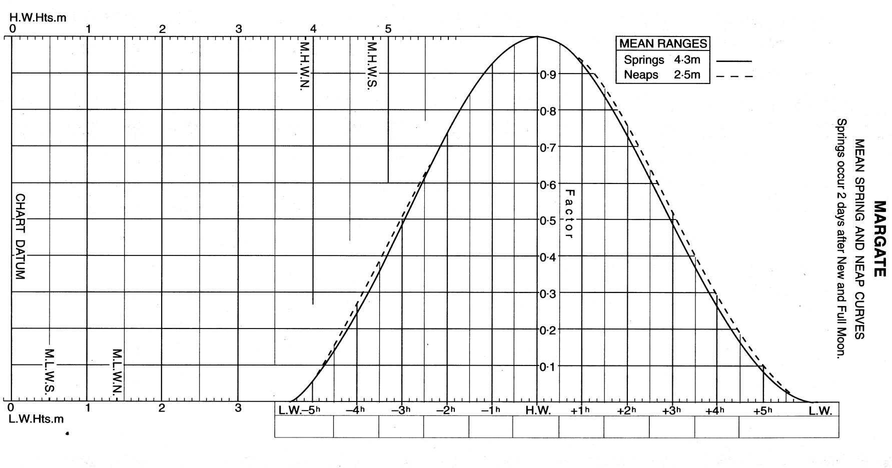
The differences for Kilkeel based on the standard port of Belfast are portrayed in the Almanac/Admiralty Tide Tables as follows:

		high water		low water		MHWS	MHWN	MLWN	MLWS
638	BELFAST…………	**0100**	**0700**	**0000**	**0600**				
		and	and	and	and	3.5	3.0	1.1	0.4
		1300	**1900**	**1200**	**1800**				
629	Kilkeel…...............	+0040	+0030	+0010	+0010	+1.2	+1.1	+0.4	+0.4
643	Red Bay…………	+0022	-0010	+0007	-0017	-1.9	-1.5	-0.8	-0.2

-

If you require the time of a tide at 1030 at Kilkeel you need to interpolate between the values for Belfast between 0700 and 1300. Some examples of this are shown later. For the heights interpolate between MHWS and MHWN for the high water height and MLWS and MLWN for low water. In the example shown above note the height difference between the spring and neap tides is very small. The difference is greater for Red Bay.

The above demonstrates calculating times and heights for high water and low water. To predict times and heights which fall between high and low water the use of mean spring and neap curves are required. These can be found on the pages adjacent to the monthly tables for the Standard port.



Interpolation

Interpolation is used to make height and time calculations. It is necessary to estimate the value between two known data points. A simple example would be: you know the time difference at 1900 hrs and the time difference at 0100 hrs, but what will the time difference be at 2036 hrs?

the two data points are:

at point A, 1900 hrs the time difference is +0015 hrs

at point B, 0100 hrs the time difference is +0010 hrs

The following three examples show how to interpolate the time difference at 2036 hrs:

Mental arithmetic (with the help of a calculator)

the number of hours between 1900 - 0100 = 6hrs = 360 minutes

the time difference between 0015 and 0010 = 0015 - 0010 = 5 minutes

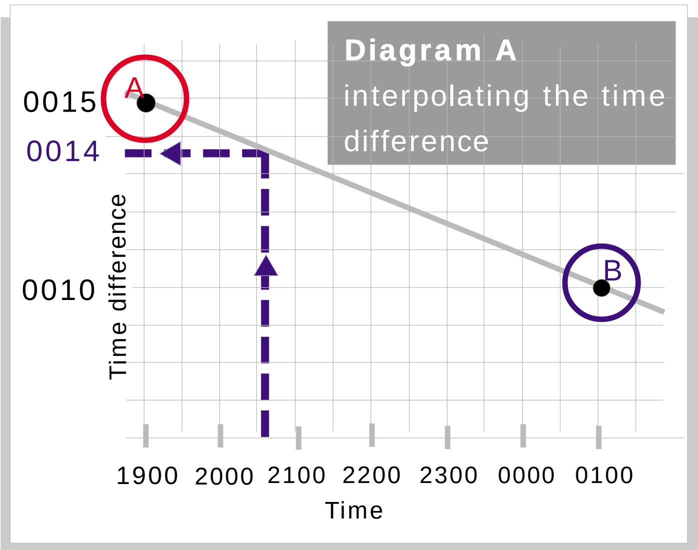
for every minute of time difference the time changes 360/5 = 72 mins

the time difference between 1900 and 2036 = 60 + 30 + 6 = 96 mins

96 / 72 = 1.33 minutes. Subtract this from 0015 = 0014 hrs to the nearest minute

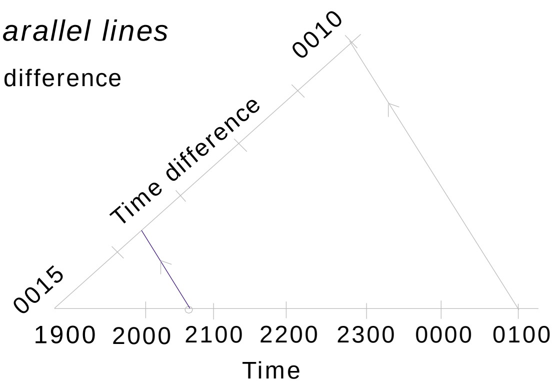
Interpolation using a grid - see diagram A

* draw a grid with the axis along the bottom marked 1900 - 0100 and the axis at the side marked between 0010 - 0015
* draw point A, where the grid lines 1900 and 0015 cross
* draw point B, where the grid 0100 and 0100 cross
* join the points A & B with a line. Mark up from the time axis 2036 to the line and across to the time difference axis. Result 0014 to the nearest minute.



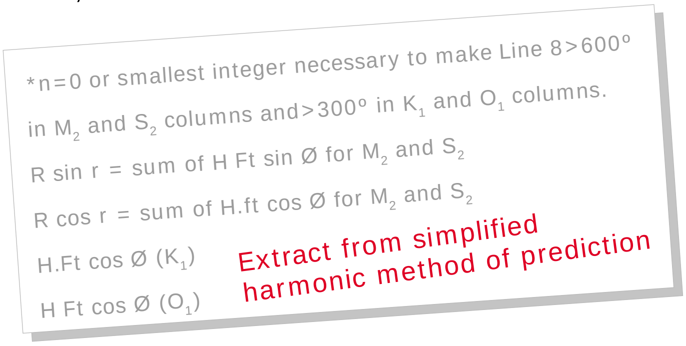
Interpolation using a triangle and parallel lines

* mark off two axes for the time and time difference with 0015 corresponding to 1900
* join the 0100 mark to the 0010 mark
* draw a parallel line from the 2036 mark to join the time difference line
* the time difference to the nearest minute is 0014



Computational methods of prediction

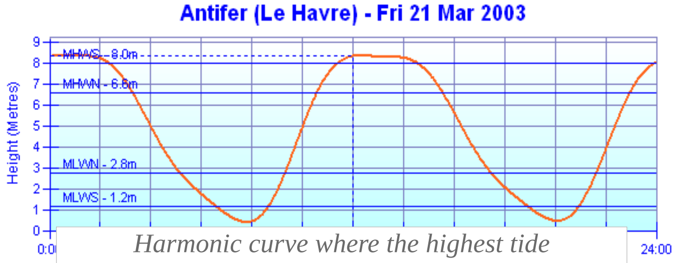
There are methods for predicting the height of tide at any specified time using mathematical calculations, these are rather complex and require a high level of maths. At a minimum they require calculators and are somewhat time consuming. In practice, their use for the small boat user is seldom practicable.


*n=0 or smallest integer necessary to make Line 8>600°
in M_2 and S_2 columns and>300° in K_1 and O_1 columns.
R sin r = sum of H Ft sin Ø for M_2 and S_2
R cos r = sum of H.ft cos Ø for M_2 and S_2
H.Ft cos Ø (K_1)
H Ft cos Ø (O_1)

Extract from simplified harmonic method of prediction

One such method has been derived by the Admiralty and can be found in the Admiralty Tide Tables; the simplified harmonic method of prediction. This works on the basis of using angles and factors relating to astronomical data, and harmonic constants taken from survey work around our shores; using this method it is possible to calculate the height of the tide at any given time. This method of prediction was primarily designed for use with a pocket calculator. The Hydrographic Office use additional constants when producing the tide tables for standard ports in their tide tables.

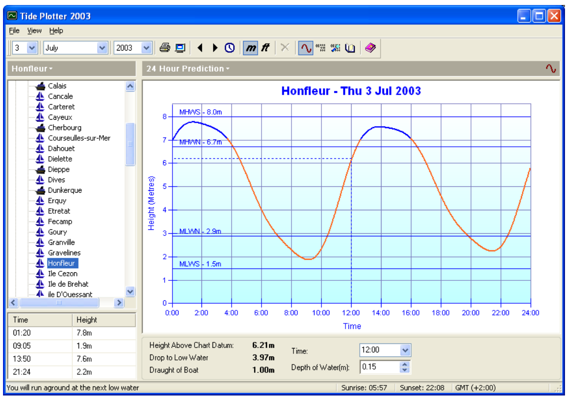
With the development and increasing sophistication of computers, programs have been developed to take out all the mathematical 'grind'. Not only do they perform thousands of calculations in a split second but also have the capability of presenting the information in graphical, easy to read and understandable formats. Taking Tide Plotter as an example, the computer program works out the height for a given port at one minute intervals throughout the day; it then determines the usually two high waters and two low waters to produce the tables. It is worth bearing in mind that with all computer programs there can be variations in the way in which the harmonic curves are interpreted. Some ports have double high or low tides, some have stands where there is a sustained period of high or low water. The Solent is a classic example where the tide coming in either side of the Isle of Wight causes such phenomena. Even with a very normal harmonic curve there is usually a period of 20 minutes when the tide maintains the same height. Is high water when it first reaches that height, the mid point or at any other point during that period? There are many examples where very reputable almanacs give high or low water with differences as much as one hour, neither are wrong in as much that the tide is, for example, at its highest at both times. The graphs presenting the daily curve can be extremely useful in obtaining a true picture of the tide. Many of the traditional methods requiring pen, pencil, calculators, the use of maths and geometry can now be carried out by computer. There is, however, the health warning that whilst information technology is wonderful and marvellous, it should not replace traditional methods but just be a useful tool to assist in the process. Computers can breakdown, the batteries go flat and problems will always occur at the most awkward and potentially dangerous time. Having the knowledge and understanding to be able to work with tides using traditional paper methods is essential and is a key component of any navigation syllabus. Some practical examples of working with traditional methods are given later in this book. Some of the computer programs that produce a host of very useful tide prediction information are:



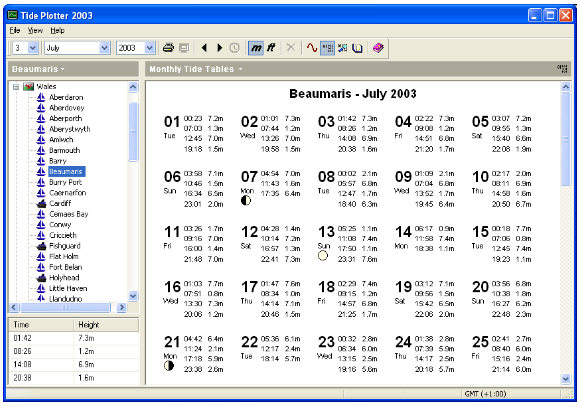
Harmonic curve where the highest tide height spans a long period of time

- ☐ *The United Kingdom Hydrographic Office product, 'TOTAL TIDE' PC version.*
- ☐ *Proudman Oceanographic Laboratory, 'POLTIPS' PC version.*
- ☐ *Belfield Software, 'TIDEPLOTTER.CO.UK' PC and Pocket PC versions.*

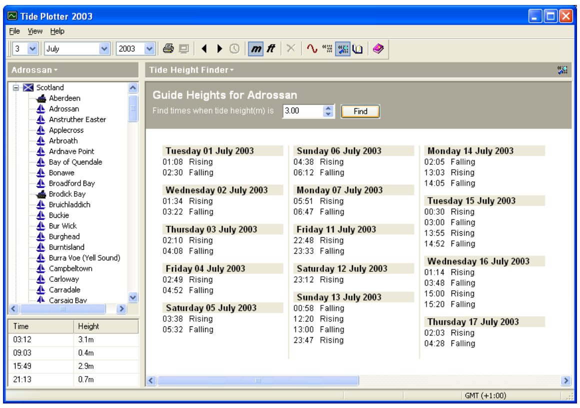
Some of the features of computational tide prediction - tideplotter.co.uk



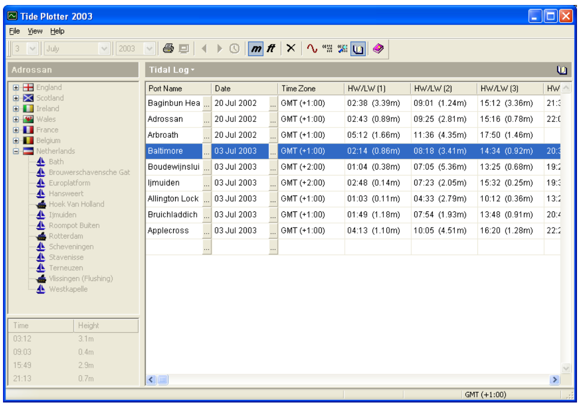
24 hr tide graph giving heights above CD, drop to LW and grounding times



Monthly tables in a similar format found in Almanacs and tide Tables



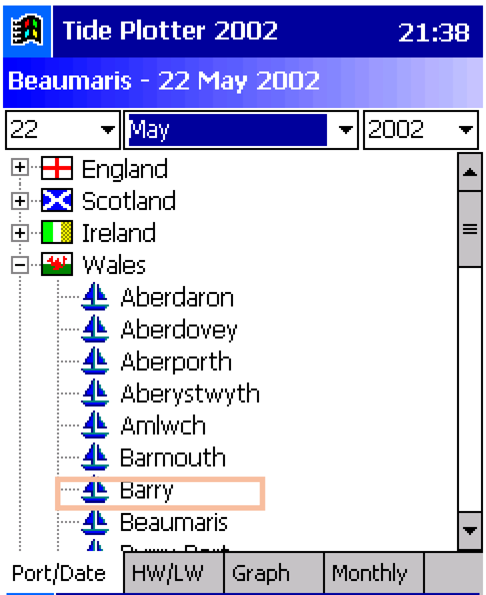
Monthly tables of tide times at a height above CD specified by the user

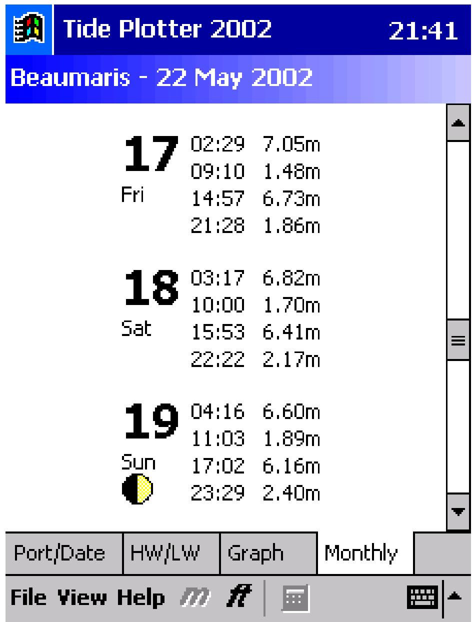


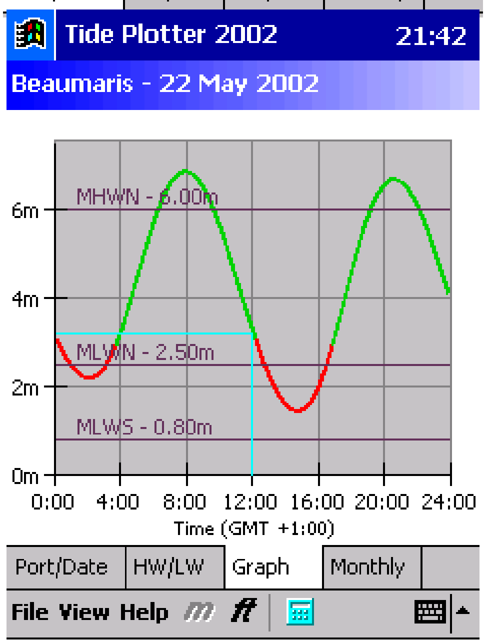
Tide Log enables the user to record tide predictions for any port on any date

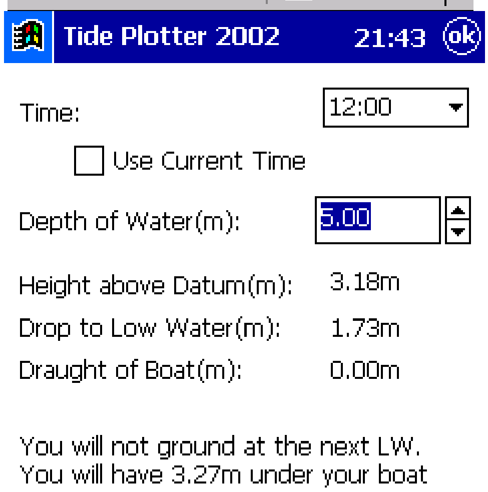
Computational predictions - Pocket PCs

A more recent development in computing is the developmen of Pocket PCs, often referred to as PDAs (Personal Digita Assistants.) Enormous processing power can now fit into the palm of your hand and be carried around in your pocket. To put this into some form of context, these miniature computers have as much computing power as a computer that would have filled a room 25 years ago. Tidal prediction programs have now been developed to work on this platform. This enables instant access to tide calculations wherever you are without having to resort to your PC. Whether in the cockpit of your boat, in the pub, or anywhere on the move a click of a button gives you the information you require. *tideplotter.co.uk* provides both the PC and Pocket PC version bundled together.









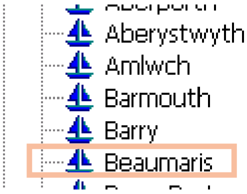
Examples of tidal information that is instantly accessible from your Pocket PC

Exercise PDA

Using the information from the Pocket PC screens adjacent. If anchored at Beaumaris at 12:00 on 22 May 2002 with 5 metre depth of water, draught of boat 1m. Will there be any clearance under the keel at Low Water and if so by how much?

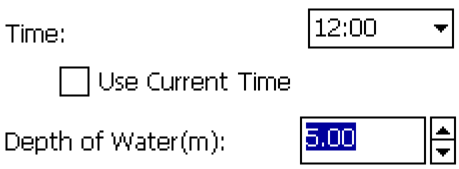
Method

1 Select Beaumaris from the list of ports

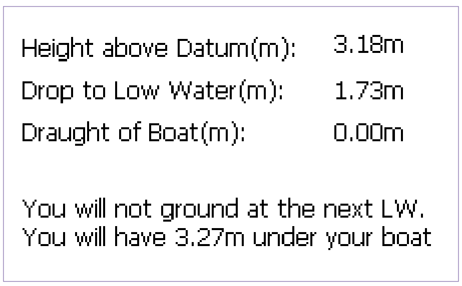


2 Enter the date

3 Enter the time and depth of water



4 Add 1 metre for boat draught (this can be pre set into computer if preferred.) Calculations are instantly displayed



Answer:

Subtracting 1m for the draught of your boat you will have a predicted 2.27m under your boat at LW

Exercise 1
What is the tide range on the 2 March at 1700 hrs? Is the tide a spring or neap tide?

ENGLAND – MARGATE

LAT 51°23′N LONG 1°23′E

TIMES AND HEIGHTS OF HIGH AND LOW WATERS

FEBRUARY m		Time	m	MARCH	Time	m		Time	m
4.9	16	0231	4.5	1	0128	5.0	16	0139	4.5
0.4		0858	0.7		0756	0.2		0757	0.7
4.8	M	1452	4.4	SU	1402	5.0	M	1354	4.4
0.7		2059	0.9		2004	[illegible]		2000	0.7
4.8	17	0301	4.4	2	0210	5.0	17	0205	4.5
0.4		0932	0.8		0840	0.2		0827	0.7
4.6	TU	1523	4.3	M	1444	4.9	TU	1420	4.4
0.8		2135	0.9		2047	0.5		2033	0.7
4.7	18	0335	4.3	3	0253	5.0	18	0233	4.4
0.6		1009	0.9		0924	0.4		0859	0.8
4.4	W	1601	4.2	TU	1526	4.7	W	1450	4.4
1.0		2216	1.1		2132	0.6		2108	0.8
4.5	19	0416	4.2	4	0340	4.8	19	0306	4.4
0.8		1052	1.1		1010	0.6		0934	0.9
4.2	TH	1648	4.0	W	1612	4.5	TH	1526	4.3
1.2		2304	1.3		2220	0.8		2147	0.9

Method

1 using the tide table above determine the HW and LW height either side of 1700 hrs

	Time	m	
1500	1444	4.9	range = 4.9 - 0.5 = 4.4 m
	2047	0.5	

2 to determine whether it is a spring or neap tide, make a comparison between the actual range on the 2 March at 1700 hrs, ie., 4.4 m, with the range between MHWS and MLWS and with the range between MHWN and MLWN. This height information can be found in the almanac.

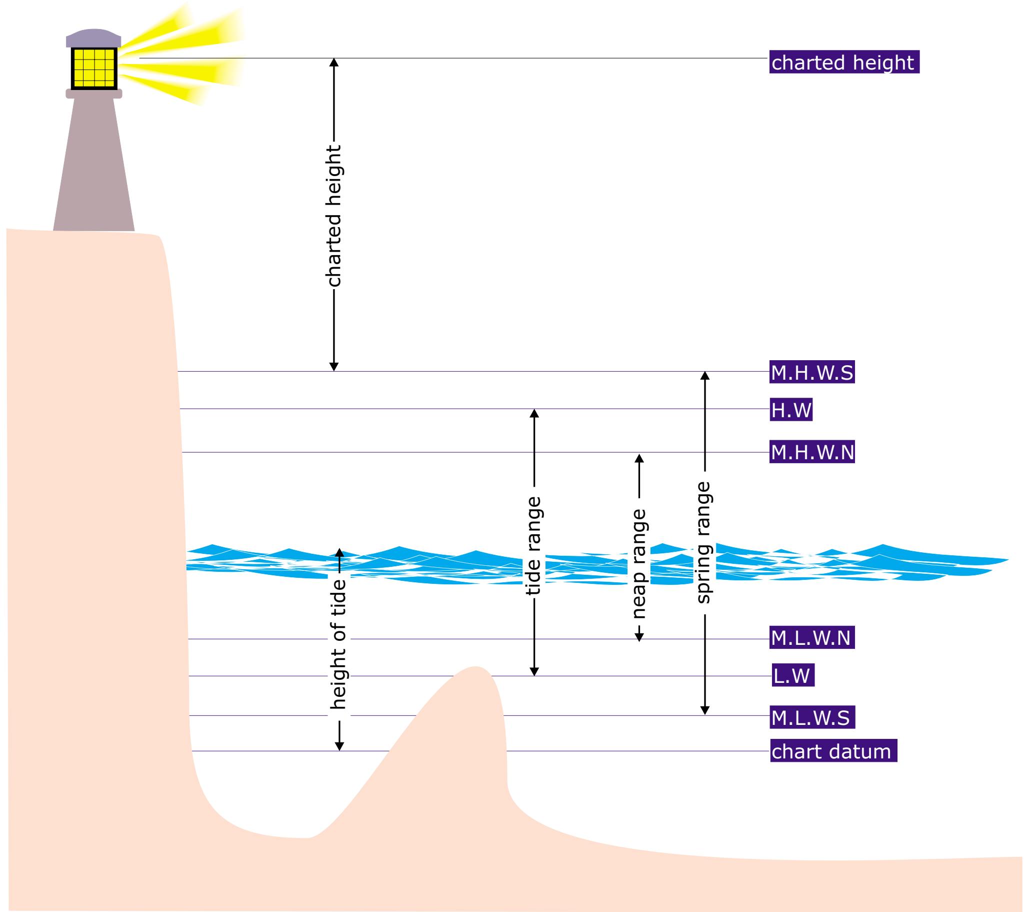
Margate	MHWS	MHWN	MLWN	MLWS
	4.8	3.9	1.4	0.5

neap range = 3.9 - 1.4 = **2.5 m**

spring range = 4.8 - 0.5 = **4.3 m**

With a range of 4.4 m at 1700 hrs on 2 March compared to a spring range of 4.3 m it can be assumed that it is a spring tide (slightly higher than the spring mean range)

Answer:
The tide range on 2 March is 4.4m. The spring range is 4.3m. The tides at that time are spring tides.



Examples of tidal ranges

Exercise 2
using the tide table adjacent for Margate, on what date am/pm will the tide range be 3.4 m? Is that range a spring or neap tide?

FEBRUARY		Time	m	MARCH		Time	m			Time	m
16	M	0231	4.5	1	SU	0128	5.0	16	M	0139	4.5
		0858	0.7			0756	0.2			0757	0.7
		1452	4.4			1402	5.0			1354	4.4
		2059	0.9			2004	0.5			2000	0.7
17	TU	0301	4.4	2	M	0210	5.0	17	TU	0205	4.5
		0932	0.8			0840	0.2			0827	0.7
		1523	4.3			1444	4.9			1420	4.4
		2135	0.9			2047	0.5			2033	0.7
18	W	0335	4.3	3	TU	0253	5.0	18	W	0233	4.4
		1009	0.9			0924	0.4			0859	0.8
		1601	4.2			1526	4.7			1450	4.4
		2216	1.1			2132	0.6			2108	0.8
19	TH	0416	4.2	4	W	0340	4.8	19	TH	0306	4.4
		1052	1.1			1010	0.6			0934	0.9
		1648	4.0			1612	4.5			1526	4.3
		2304	1.3			2220	0.8			2147	0.9

Method

1 Subtract the LW height from the HW height to ascertain the tide range. The following tides have a range of 3.4:
17 February pm, 19 March am & pm,18 February am.

2 The range of 3.4 m falls exactly mid way between the spring range of 4.3 and the neap range of 2.5.
That is (4.3+2.5)/2 = 3.4

Answer:
The tide will have a range of 3.4m on: 17/18 February and 19 March.
This range of tide is exactly mid way between springs and neaps.

Exercise 3
Calculate HW time (BST) and height at a secondary port.
At what times will it be HW (pm) at Ardglass on 16 October. What will the HW height be?

Need to know....

Standard port for Ardglass?
HW time and height for standard port.
Time and height differences on standard port

NORTHERN IRELAND – BELFAST

LAT 54°36′N LONG 5°55′W

T(GMT)

TIMES AND HEIGHTS OF HIGH AND LOW WATERS

PTEMBER			OCTOBER						NOVEMBER					
	Time	m		Time	m		Time	m		Time	m		Time	m
16	0117	1.0	1	0046	1.2	16	0206	0.9	1	0214	0.8	16	0306	0.8
	0749	3.1		0645	2.9		0830	3.1		0821	3.3		0934	3.2
W	1400	1.1	TH	1311	1.3	F	1435	1.1	SU	1432	1.0	M	1532	1.0
	2004	3.3		1910	3.1		2036	3.3		2035	3.5		2140	3.4
17	0232	0.9	2	0155	1.0	17	[illegible]	0.8	2	0303	0.6	17	0343	0.8
	0851	3.2		0758	3.1		0919	3.2		0912	3.5		1012	3.3
TH	1458	1.0	F	1415	1.1	SA	1525	0.9	M	1519	0.8	TU	1608	0.9
	2100	3.4		2015	3.3		2125	3.4		2125	3.6		2219	3.4
18	0330	0.7	3	0249	0.8	18	0350	0.7	3	0347	0.4	18	0415	0.8
	0941	3.3		0855	3.3		1002	3.3		0958	3.6		1047	3.3
F	1547	0.9	SA	1504	0.9	SU	1606	0.9	TU	1602	0.7	W	1640	0.9
	2148	3.5		2106	3.5		2208	3.5		2212	3.7		2253	3.4
19	0417	0.7	4	0335	0.6	19	0425	0.7	4	0429	0.4	19	0447	0.8
	1025	3.3		0941	3.5		1040	3.3		1043	3.7		1117	3.4
SA	1630	0.8	SU	1547	0.7	M	1640	0.8	W	1644	0.6	TH	1711	0.9
	2231	3.6		2150	3.6		2246	3.5	O	2259	3.8	●	2323	3.4

Method

1 Standard port for Ardglass is BELFAST, where the HW time on 16 October (pm) = 2036 hrs GMT, height = 3.3 m. Time and height differences for Ardglass are shown in diagram D.

2 Using interpolation as shown in diagram A, work out the time difference for Ardglass at 2036 hrs. The difference is shown by the blue dashed line at +0014.

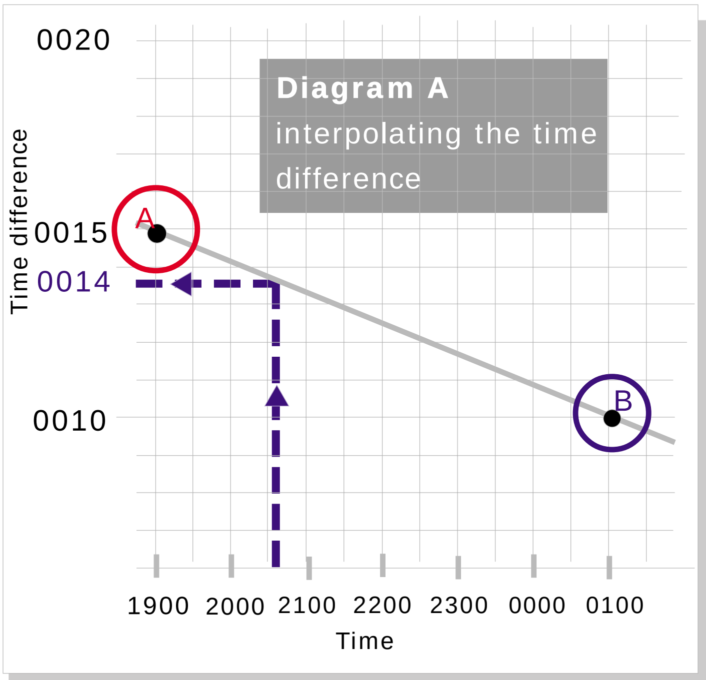
3 Add the time difference to HW at Belfast 2036 + 0014 = 2050 hrs GMT. Add one hour to give BST = 2150 hrs

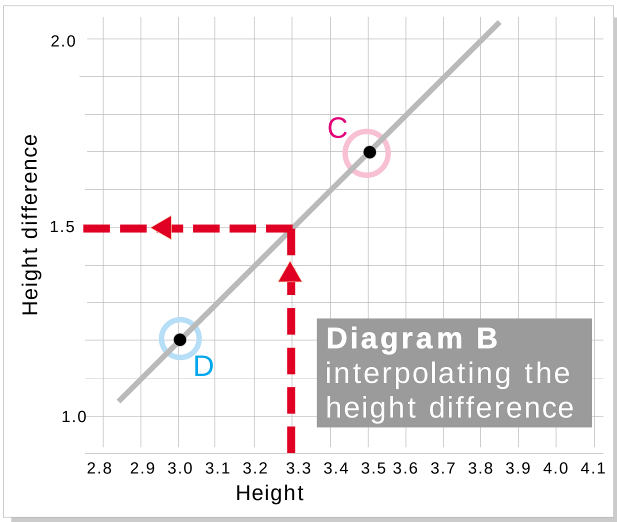
4 To find the height use interpolation again as shown in diagram B. Height at BELFAST = 3.3m, height difference for Ardglass = +1.5m
Height at Ardglass =3.3 + 1.5 = 4.8m

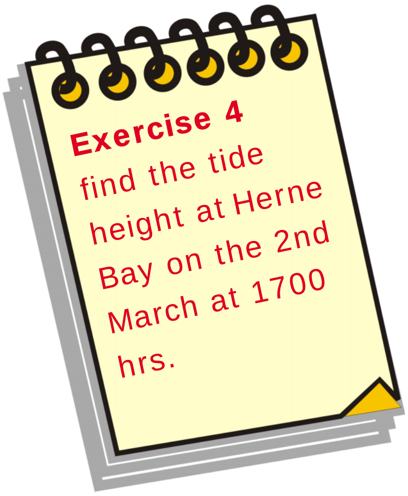
Answer:
HW at Ardglass = 2150 hrs BST
Height at Ardglass = 4.8m

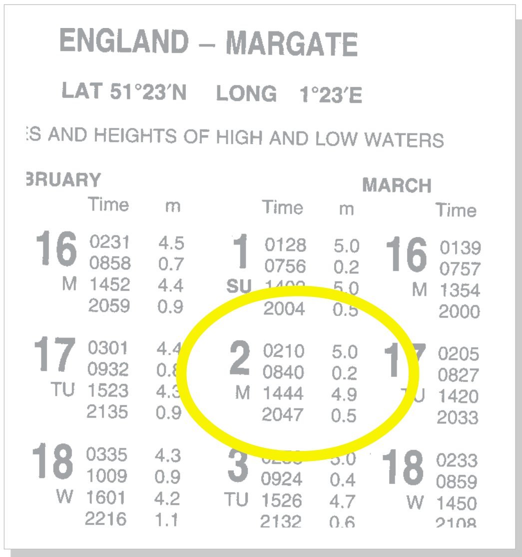
		high water		low water		MHWS	MHWN	MLWN	MLWS
638	BELFAST…………	**0100** and **1300**	**0700** and **1900**	**0000** and **1200**	**0600** and **1800**	3.5	3.0	1.1	0.4
631	Ardglass.................	+0010	+0015	+0005	+0010	+1.7	+1.2	+0.6	+0.3

Diagram D
secondary port detail









Method

1 find the Standard port for Herne Bay (MARGATE) see opposite in diagram D

2 find the HW time for Margate nearest to 1700 hrs; this is available from your Tide Tables (1444 hrs,) see above highlighted in yellow

3 find the time difference for HW at Herne Bay. This can be obtained by interpolation as shown in diagram A.

1444 hrs (HW MARGATE)
+ 0030 (time difference)
HW Herne Bay = 1514 hrs

4 find the height of the HW at Herne Bay, see diagram B, (4.8m HW Margate + 0.4m height difference) = **5.2m**. For LW there is no need to draw a diagram to interpolate as the height difference is 0.0m and we know it is on LW springs at **0.5m**.

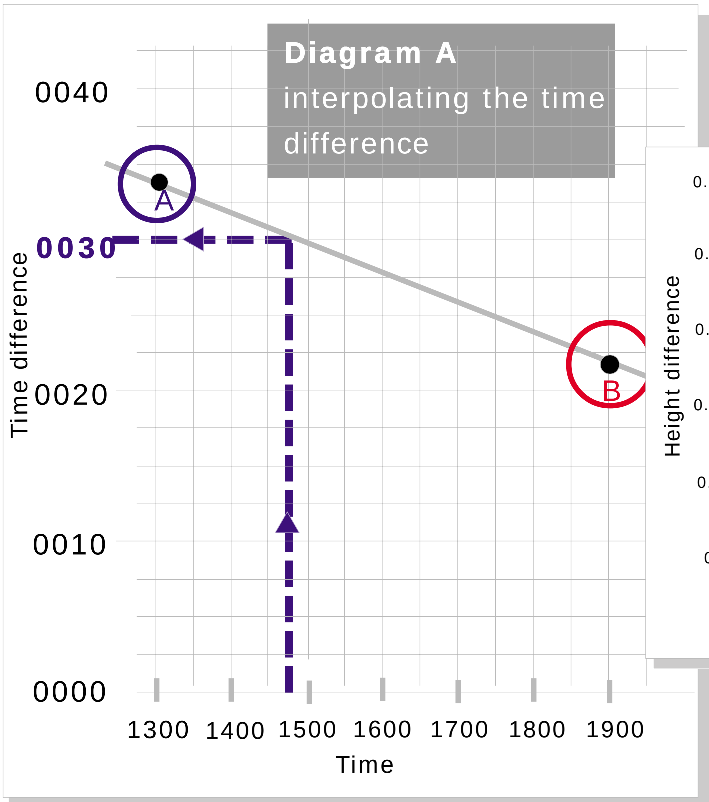
5 Draw a **straight line** on the curves graph, diagram C, joining the 5.2 HW point to the 0.5 LW point

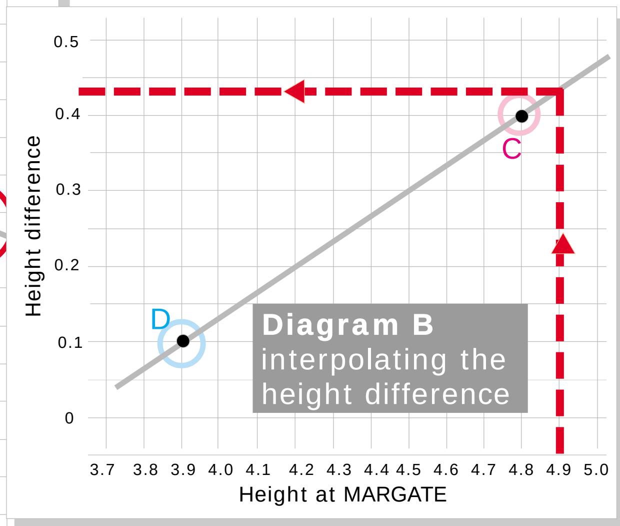
6 enter the HW time for Herne Bay 1514 hrs in the HW box at the bottom of the curves graph, diagram C. In the adjacent boxes enter HW +1hr until you span the time you require (1700 hrs)

7 draw **a line up from the 1700 hrs point** to join the spring curve. From that draw a **horizontal line across** to meet the **straight line** connecting the HW and LW points. Draw a **vertical line** to intersect the tide height line. From that point (F) you can read off the tide height 4.2m.

Answer:
Herne Bay at 1700 hrs on the 2 March the tide height is predicted to be 4.2m above chart datum.

Important, please note, all data used in these examples is theoretical and should not be used for navigation.

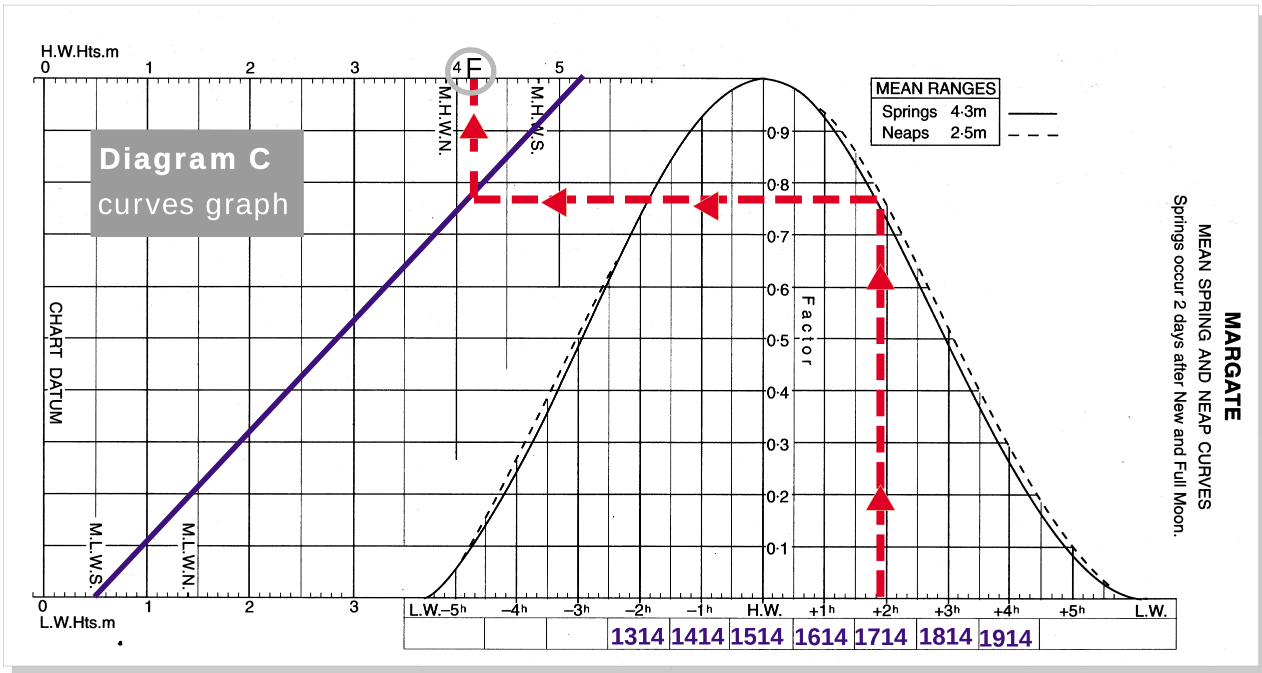




Interpolation of times and heights, in practice, can often be worked out with mental arithmetic. This graphical method is not always appropriate when calculations are needed quickly

Diagram D
secondary port detail

		high water		low water		MHWS	MHWN	MLWN	MLWS
103	MARGATE............	0100	0700	0100	0700				
		and	and	and	and	4.8	3.9	1.4	0.5
		1300	1900	1300	1900	C	D		
104	Herne Bay.................	A +0034	B +0022	+0015	+0032	+0.4	+0.1	+0.0	+0.0



Exercise 5
will the ship against the wall take the ground at low water? What will be the clearance under the keel at LW

date: 2 March
time: 1700 hrs
place: Herne Bay
draught: 2m
depth sounding from waterline: 6.5m

Need to know....

Height of tide at 1700 hrs
Height of tide at low water
Drop of tide to low water

Method

1 from exercise 4 we have determined that the height of the tide at 1700 hrs at Herne Bay on the 2 March is 4.2m

2 we need to establish the height of the tide at the next LW. To do this we take the next LW height at the standard port MARGATE (0.5m in the tide table opposite highlighted in yellow) and work out the height difference for Herne Bay. Using the diagram D the LW height difference is 0.0m. Therefore the LW height is 0.5m

3 We now have the following information:

height at 1700 hrs	= 4.2 m
height at LW	= 0.5 m
draught	= 2.0 m
depth of water from sounder reading	= 6.5 m (from waterline)
clearance under keel at 1700 hrs	= depth reading - draught
drop to LW	= height at 1700hrs - height at LW
	= 4.2 - 0.5 = 3.7 m

4 the depth of the water under the keel at LW will be:

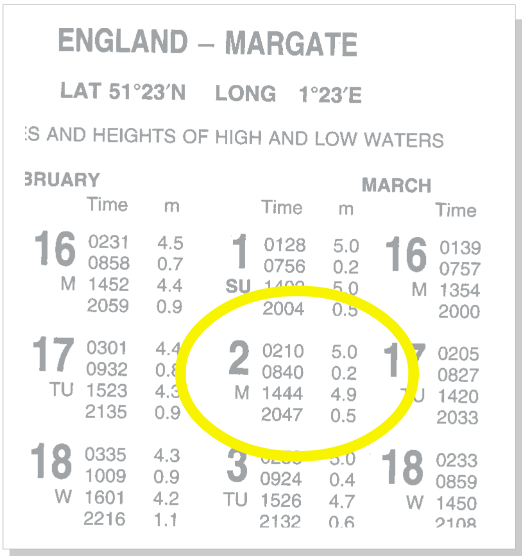
= depth sounder reading - (height at 1700 hrs - height at LW) - draught

= 6.5 m - (4.2 m - 0.5 m) - 2.0 m

= 0.8 m clearance under keel at LW

Answer:
The ship will not ground at LW. The predicted clearance under the keel will be 0.8m

Important, please note, all data used in these examples is theoretical and should not be used for navigation.



ENGLAND – MARGATE

LAT 51°23′N LONG 1°23′E

:S AND HEIGHTS OF HIGH AND LOW WATERS

3RUARY						MARCH	
	Time	m		Time	m		Time
16 M	0231 0858 1452 2059	4.5 0.7 4.4 0.9	1 SU	0128 0756 1400 2004	5.0 0.2 5.0 0.5	16 M	0139 0757 1354 2000
17 TU	0301 0932 1523 2135	4.4 0.8 4.3 0.9	2 M	0210 0840 1444 2047	5.0 0.2 4.9 0.5	17 TU	0205 0827 1420 2033
18 W	0335 1009 1601 2216	4.3 0.9 4.2 1.1	3 TU	0250 0924 1526 2132	5.0 0.4 4.7 0.6	18 W	0233 0859 1450 2108

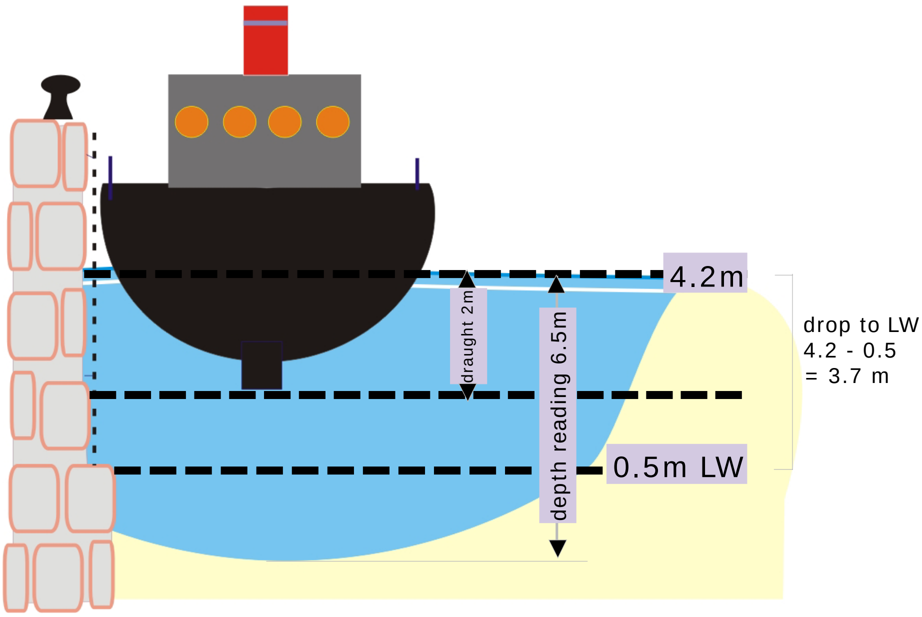


Diagram D
secondary port detail

		high water		low water		MHWS	MHWN	MLWN	MLWS
103	MARGATE............	**0100** and **1300**	**0700** and **1900**	**0100** and **1300**	**0700** and **1900**	4.8	3.9	1.4	0.5
104	Herne Bay................	+0034	+0022	+0015	+0032	+0.4	+0.1	+0.0	+0.0

Exercise 6
calculating clearance heights.

Will the ship passing under the bridge at Margate on 19 Feb at 1945 hrs., have sufficient clearance? If so, by how much?

Need to know....

height of water at 1945 hrs = 2.8m
height of ship above waterline = 4.2m
height of MHWS above CD, diagram D = 4.8m
height of top of ship above CD = 7.0m
charted clearance of bridge above MHWS = 3.2m

Method

1 establish height of water at 1945 hrs. Enter HW time for MARGATE (1648hrs) in the box at bottom of the curves graph, diagram C. Draw a line up from the 1945 hr time mark to the curve; across to height line and then up to height scale. The height reading is 2.8 m (This method is detailed in exercise 4)

2 establish the height of MHWS (4.8m);
the charted height of the bridge is 3.2 m.

3 the height of the ship above the waterline is 4.2 m, added to the current height of water above chart datum at 1945 hrs, gives the height of the ship above chart datum = 2.8 + 4.2 =7.0m

4 the height above chart datum of the bridge, is MHWS height + charted height = 4.8 +3.2 = 8.0m

5 to calculate the clearance (?) we need to take the height of the bridge above chart datum and subtract from it the height of the ship above chart datum.

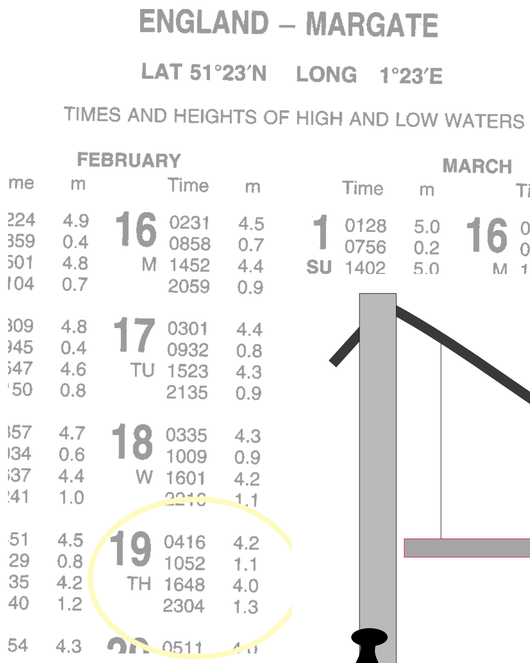
= (height of MHWS + charted height) - (height of water above CD + height of ship above waterline)

= (4.8 + 3.2) - (2.8 + 4.2)

= 8.0 - 7.0

= 1.0 m clearance

Answer:
The ship will have a predicted 1.0m clearance passing under the bridge at 1945 hrs on 19 March



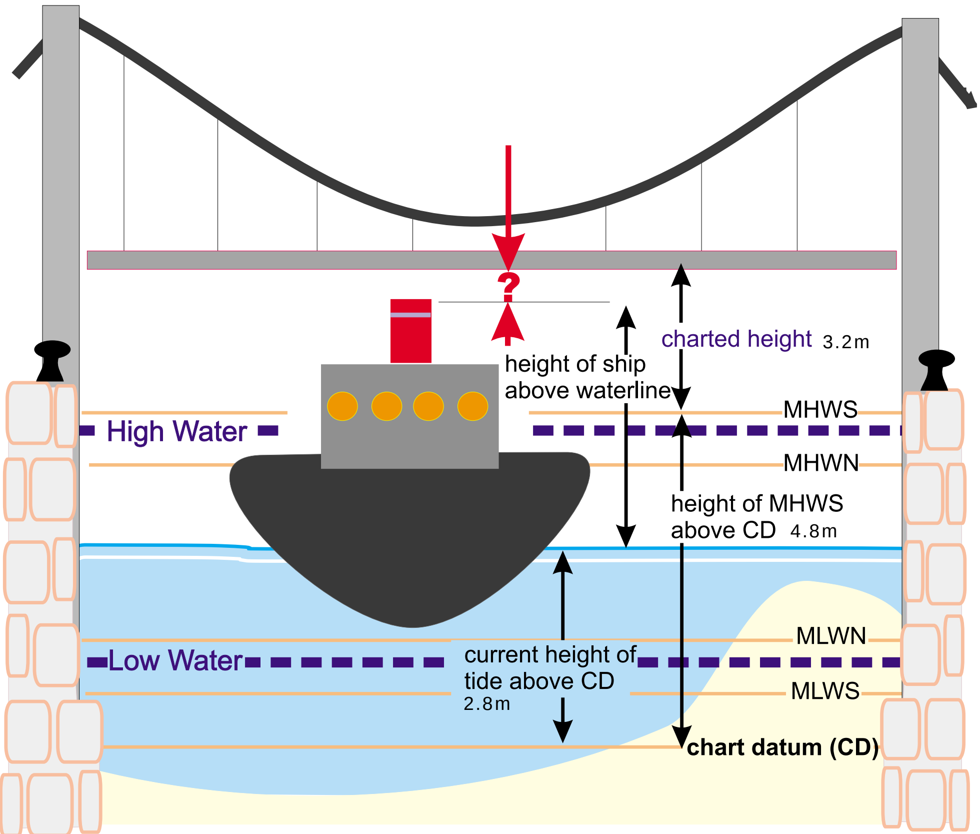
ENGLAND – MARGATE

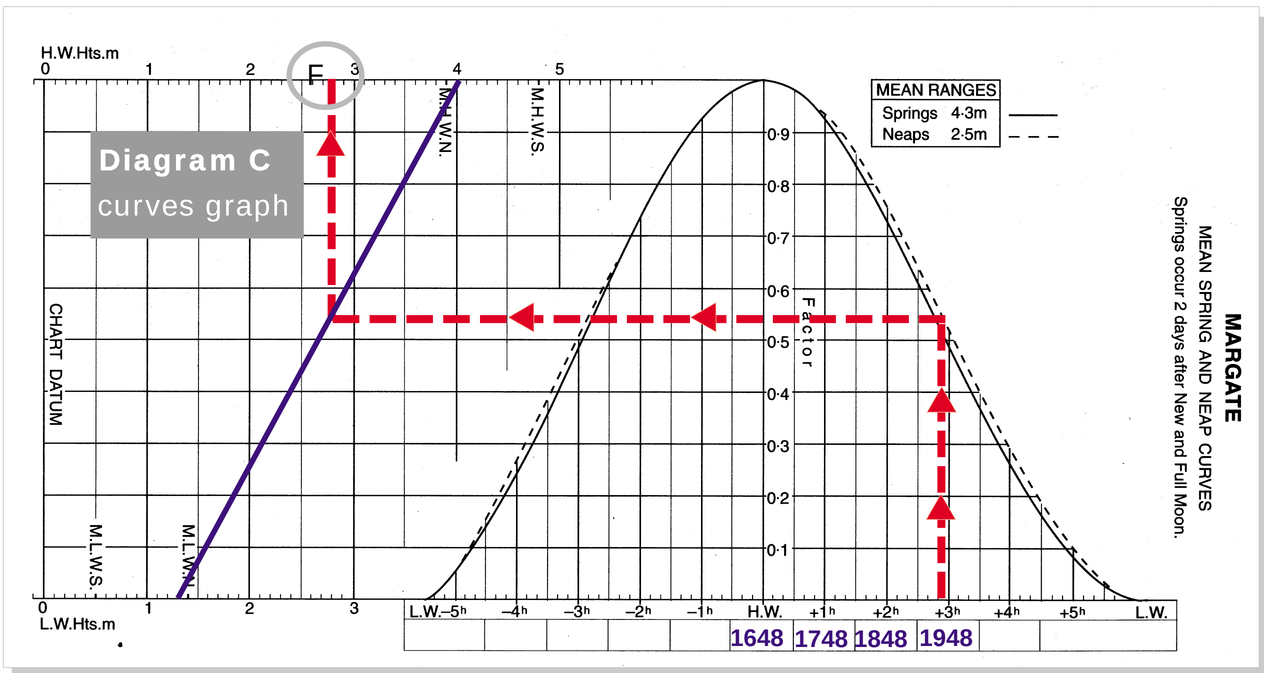
LAT 51°23′N LONG 1°23′E

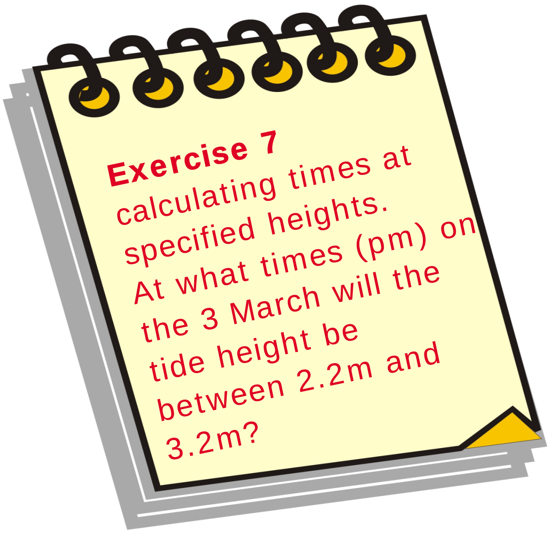
TIMES AND HEIGHTS OF HIGH AND LOW WATERS

FEBRUARY						MARCH					
me	m		Time	m			Time	m		Time	m
224	4.9	16	0231	4.5		1	0128	5.0	16	0139	4.5
359	0.4		0858	0.7			0756	0.2		0757	0.7
501	4.8	M	1452	4.4		SU	1402	5.0	M	1354	4.4
104	0.7		2059	0.9							
309	4.8	17	0301	4.4							
945	0.4		0932	0.8							
547	4.6	TU	1523	4.3							
50	0.8		2135	0.9							
357	4.7	18	0335	4.3							
034	0.6		1009	0.9							
637	4.4	W	1601	4.2							
241	1.0		2210	1.1							
51	4.5	19	0416	4.2							
29	0.8		1052	1.1							
35	4.2	TH	1648	4.0							
40	1.2		2304	1.3							
54	4.3	20	0511	4.0							

Margate	MHWS	MHWN	MLWN	MLWS
Diagram D Mean levels	4.8	3.9	1.4	0.5







MARGATE

LONG 1°23′E

HIGH AND LOW WATERS

MARCH

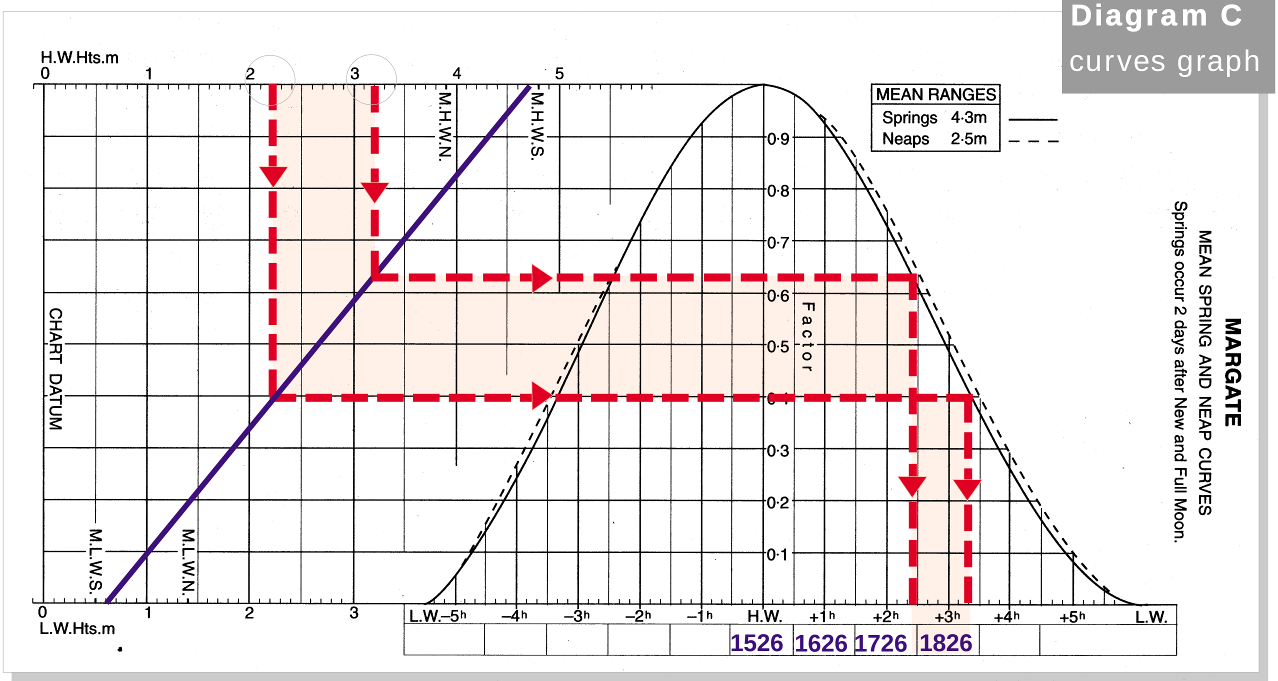
	Time	m		Time	m
1 SU	0128 0756 1402 2004	5.0 0.2 5.0 0.5	16 M	0139 0757 1354 2000	4.5 0.7 4.4 0.7
2 M	0210 0840 1444 [illegible]	5.0 0.2 4.9 0.5	17 TU	0205 0827 1420 2033	4.5 0.7 4.4 0.7
3 TU	0253 0924 1526 2132	5.0 0.4 4.7 0.6	18 W	0233 0859 1450 2108	4.4 0.8 4.4 0.8
4 W	[illegible] 1010 1612 2220	4.8 0.6 4.5 0.8	19 TH	0306 0934 1526 2147	4.4 0.9 4.3 0.9

Method

1 Determine the LW and HW heights for that day (0.6m & 4.7m,) see table above highlighted in yellow. Mark them on the top and bottom line of the curves graph, diagram C. Join the two points together, see blue line.

2 From the 2.2 and the 3.2 points draw down to meet the blue line, across to meet the far curve and down to intersect the time boxes at the bottom. These time boxes start with the HW time (1526 hrs) in the middle box. Work out the times that are intersected by the two lines. In this case the time is 1746 hrs to 1846 hrs.

Diagram C
curves graph



Exercise 8
what is the direction and rate of the tidal stream at diamond B -see chart below -on the 3 March at 1730 hrs?

		A Lat.Long			B Lat.Long		
			rate (kn)			rate (kn)	
		Dir	Sp	Np	dir	Sp	Np
before HW	6	327	1.5	0.6	243	0.6	0.2
	5	338	1.9	0.8	281	0.7	0.3
	4	355	2.1	0.9	309	1.0	0.3
	3	009	1.9	0.8	335	0.7	0.2
	2	015	1.4	0.6	357	1.0	0.4
	1	005	0.7	0.3	021	1.0	0.3
1526	**HW**	**162**	**1.0**	**0.4**	**070**	**0.9**	**0.3**
1626	1	169	2.0	0.8	100	0.8	0.3
1726	2	175	2.3	0.8	129	0.8	0.3
1826	3	171	1.8	0.7	148	0.8	0.3
after HW	4	171	1.4	0.6	176	0.6	0.2
	5	257	0.5	0.2	207	0.9	0.3
	6	320	1.3	0.5	220	0.7	0.2

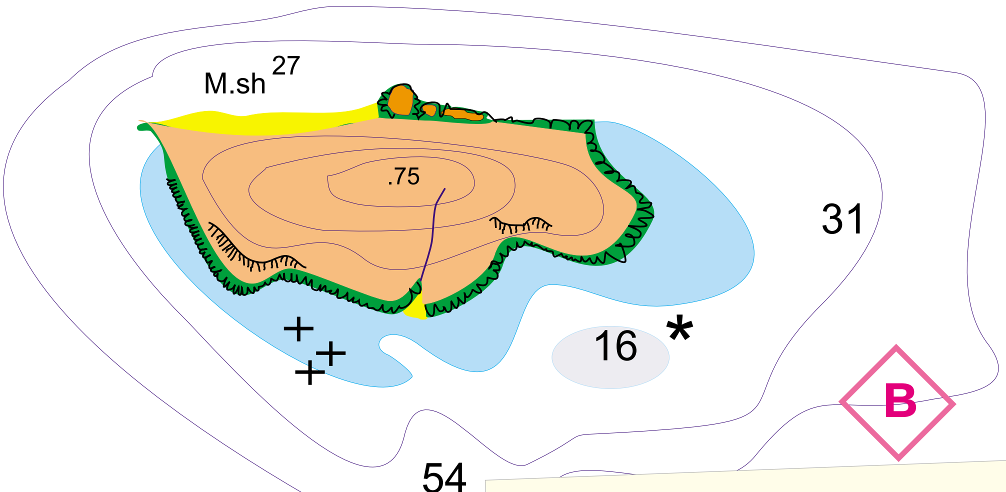
		high water		low water		MHWS	MHWN	MLWN	MLWS
103	MARGATE............	**0100**	**0700**	**0100**	**0700**	4.8	3.9	1.4	0.5

Method

1 Ascertain HW nearest to 1730 hrs from the monthly table opposite, this is 1526 hrs. Write that against the HW on the tidal diamond matrix above, plus the three subsequent hourly times after HW. The nearest time to 1730 hr is 1726 hr, 1730 hrs is 0204 hrs after HW.

2 Ascertain whether the tide is spring or neap, in this case MHWS = 4.8m and the height on the 3 March = 4.7m.

By interpolation the direction is 129º + 1º for the additional 4 minutes, [4/60 x (148-129) = 1.27 minutes], there is no difference in the spring rate of 0.8 kns.



Answer:
At tide diamond B the direction is 130 degrees and the rate 0.8 knots.

Using the monthly tide table, secondary port difference tables and tide curves graph, answer the following questions. The answers are shown overleaf.

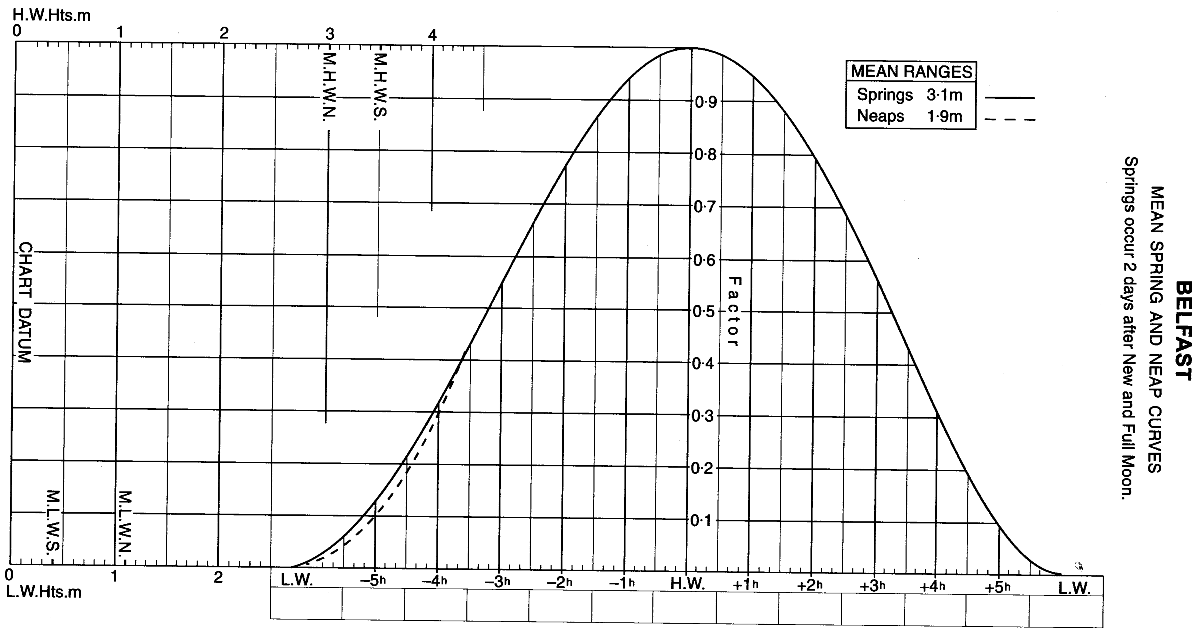
1 What is the height of the tide at Ardglass at 1915 hrs (GMT) on 17 October?

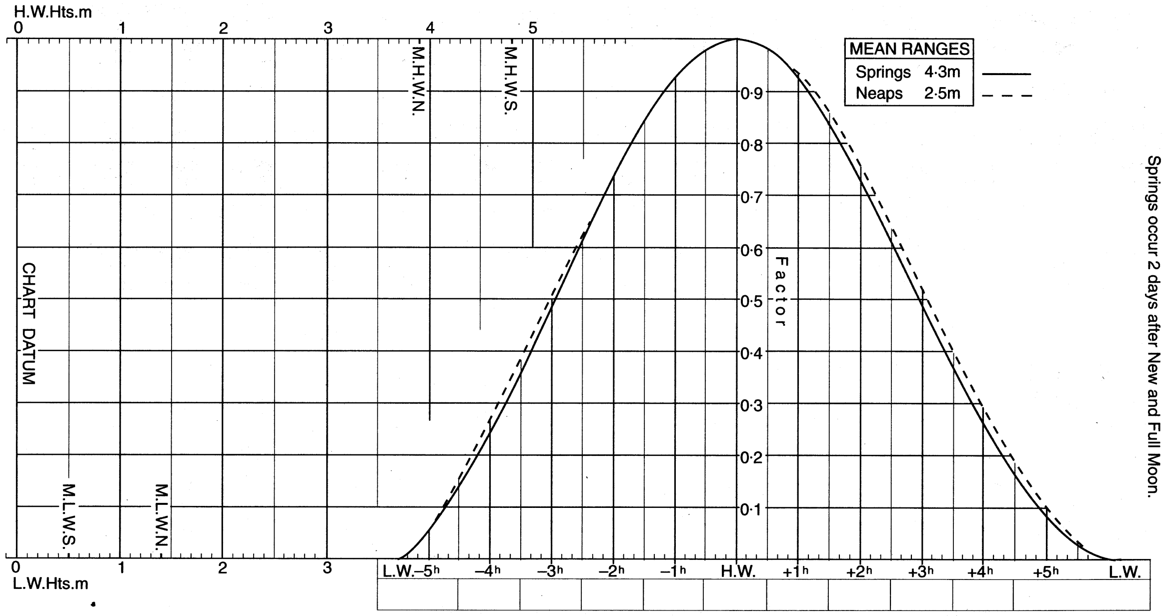
2 At what time in the morning (GMT) will the tide be at a height of 2 metres on 18 October at Ardglass?

3 You have just anchored at Margate on 3 March, the time is 1130hrs, the draught of your boat is 1.5m and the depth sounder reads 3.8m from the waterline. What will be the clearance under your keel at the next Low Water?

4 On 2 November at 1300 hrs., you are passing under a bridge at Belfast. The charted height of the bridge is 13m, the height of your mast above water level is 12.5m. What will be the clearance between the top of your mast and the bridge?

secondary port table		high water		low water		MHWS	MHWN	MLWN	MLWS
638	BELFAST............	**0100**	**0700**	**0000**	**0600**				
		and	and	and	and	3.5	3.0	1.1	0.4
		1300	**1900**	**1200**	**1800**				
631	Ardglass.................	+0010	+0015	+0005	+0010	+1.7	+1.2	+0.6	+0.3





MARGATE
MEAN SPRING AND NEAP CURVES
Springs occur 2 days after New and Full Moon.

Secondary port table		high water		low water		MHWS	MHWN	MLWN	MLWS
103	MARGATE…………	**0100**	**0700**	**0100**	**0700**				
		and	and	and	and	4.8	3.9	1.4	0.5
		1300	**1900**	**1300**	**1900**				
104	Herne Bay…...............	+0034	+0022	+0015	+0032	+0.4	+0.1	+0.0	+0.0

NORTHERN IRELAND – BELFAST

LAT 54°36′N LONG 5°55′W

TIMES AND HEIGHTS OF HIGH AND LOW WATERS

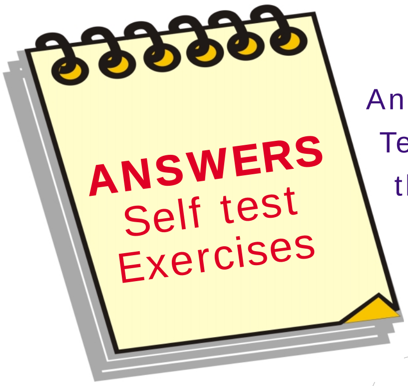
m	OCTOBER	Time	m	NOVEMBER	Time	m		Time	m
1.2	**16**	0206	0.9	**1**	0214	0.8	**16**	0306	0.8
2.9		0830	3.1		0821	3.3		0934	3.2
1.3	F	1435	1.1	**SU**	1432	1.0	M	1532	1.0
3.1		2036	3.3		2035	3.5		2140	3.4
1.0	**17**	0306	0.8	**2**	0303	0.6	**17**	0343	0.8
3.1		0919	3.2		0912	3.5		1012	3.3
1.1	SA	1525	0.9	M	1519	0.8	TU	1608	0.9
3.3		2125	3.4		2125	3.6		2219	3.4
0.8	**18**	0350	0.7	**3**	0347	0.4	**18**	0415	0.8
3.3		1002	3.3		0958	3.6		1047	3.3
0.9	**SU**	1606	0.9	TU	1602	0.7	W	1640	0.9
3.5		2208	3.5		2212	3.7		2253	3.4
0.6	**19**	0425	0.7	**4**	0429	0.4	**19**	0447	0.8
3.5		1040	3.3		1043	3.7		1117	3.4
0.7	M	1640	0.8	W	1644	0.6	TH	1711	0.9
3.6		2246	3.5	O	2259	3.8	●	2323	3.4

ENGLAND – MARGATE

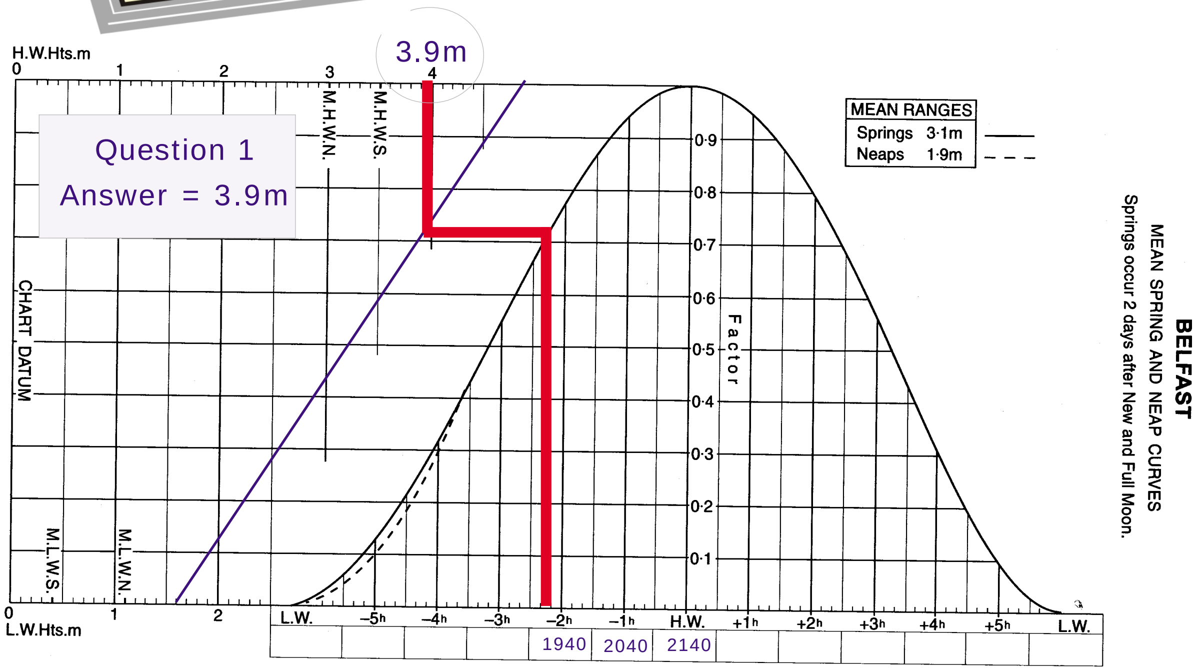
LAT 51°23′N LONG 1°23′E

IES AND HEIGHTS OF HIGH AND LOW WATERS

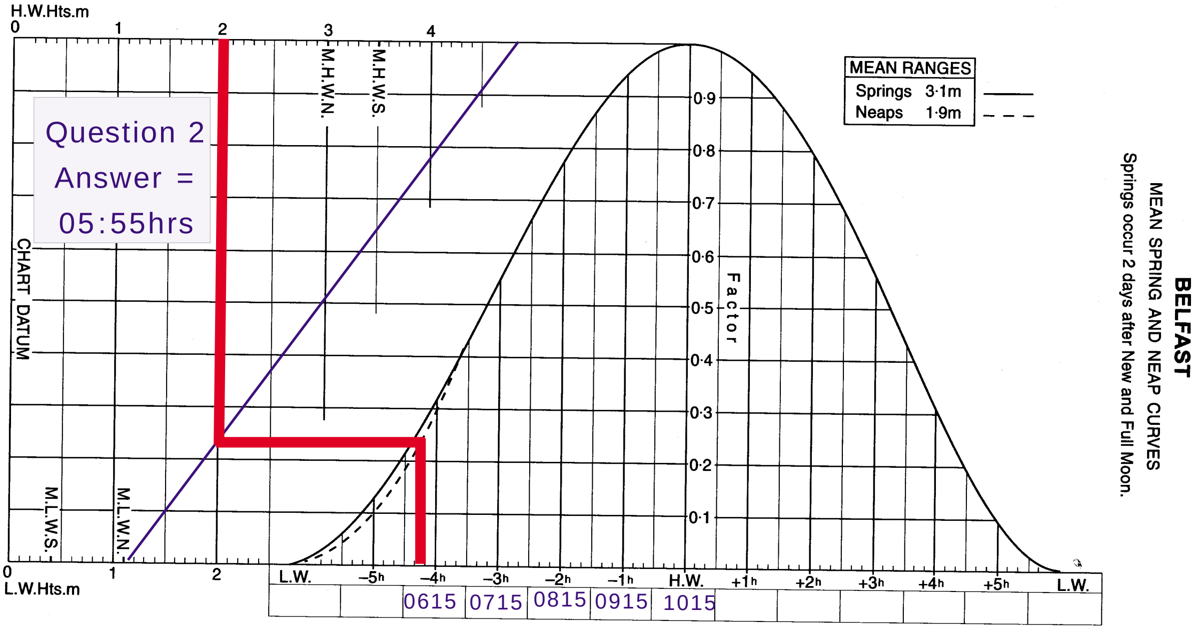
EBRUARY	Time	m	MARCH	Time	m		Time	m
16	0231	4.5	**1**	0128	5.0	**16**	0139	4.5
	0858	0.7		0756	0.2		0757	0.7
M	1452	4.4	**SU**	1402	5.0	M	1354	4.4
	2059	0.9		2004	0.5		2000	0.7
17	0301	4.4	**2**	0210	5.0	**17**	0205	4.5
	0932	0.8		0840	0.2		0827	0.7
TU	1523	4.3	M	1444	4.9	TU	1420	4.4
	2135	0.9		2047	0.5		2033	0.7
18	0335	4.3	**3**	0253	5.0	**18**	0233	4.4
	1009	0.9		0924	0.4		0859	0.8
W	1601	4.2	TU	1526	4.7	W	1450	4.4
	2216	1.1		2132	0.6		2108	0.8
19	0416	4.2	**4**	0340	4.8	**19**	0306	4.4
	1052	1.1		1010	0.6		0934	0.9
TH	1648	4.0	W	1612	4.5	TH	1526	4.3
	2304	1.3		2220	0.8		2147	0.9



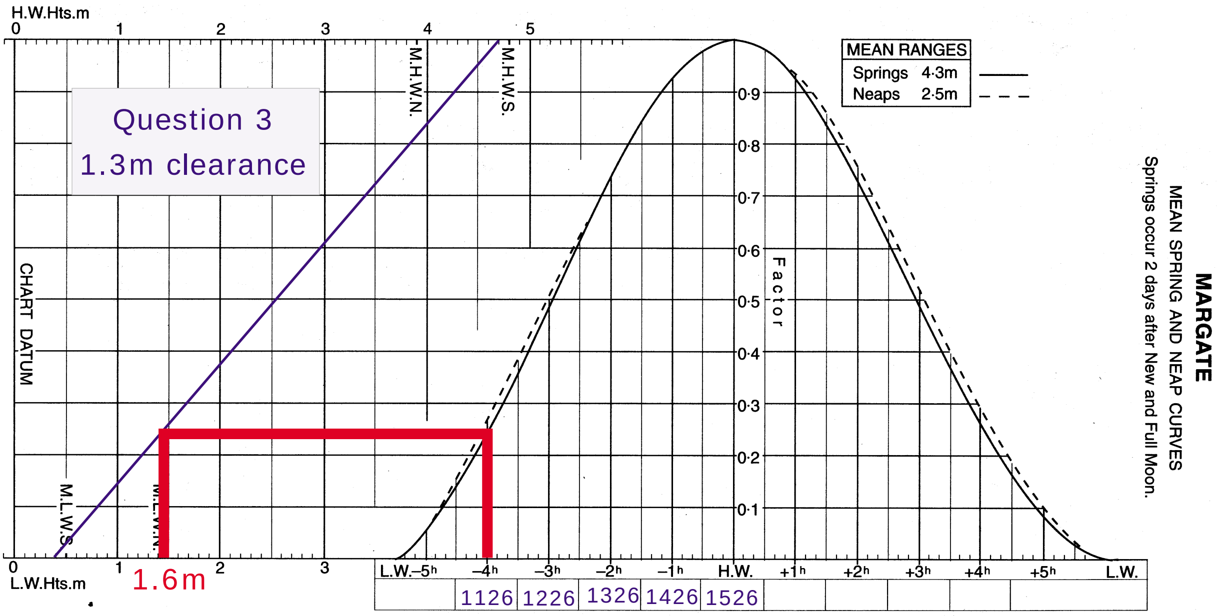
Answers to the Self Test Exercises from the previous page



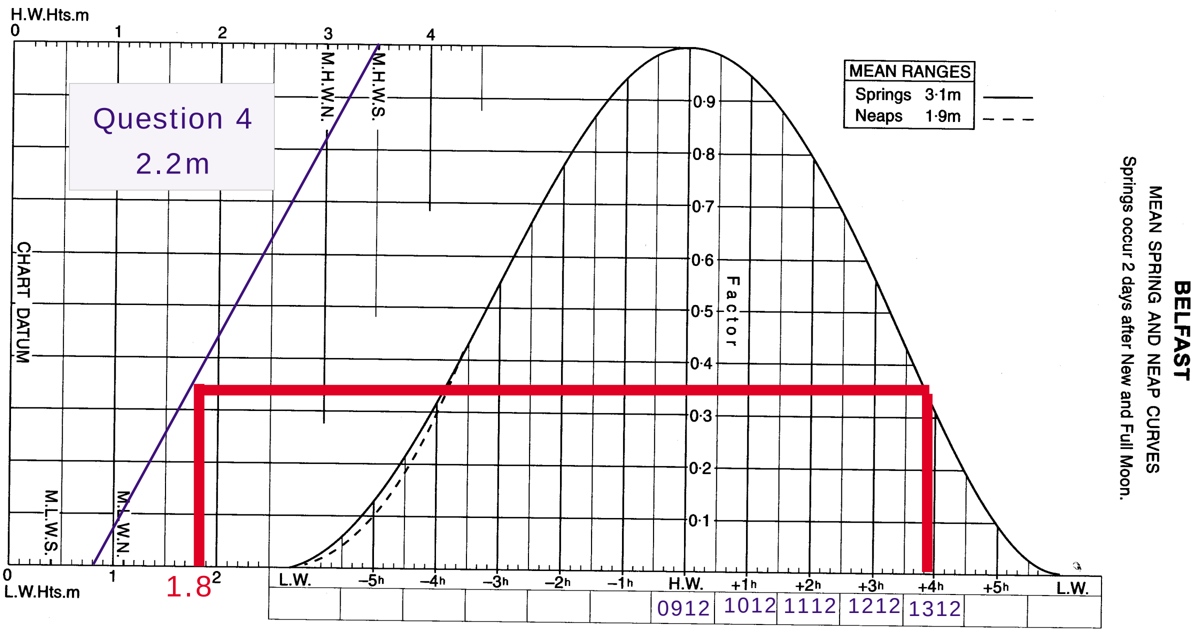
Process:
1. Establish HW time at Ardglass
2. Establish HW and LW heights for Ardglass and mark blue line on curves graph
3. Mark up from time 1915 hrs on curves graph, across onto blue height line



Process:
1. Establish HW time at Ardglass
2. Establish HW and LW heights for Ardglass and mark blue line on curves graph
3. Markdown from 2m mark to blue height line, across to curves graph and down to establish time



Height of tide above CD at 1130hrs	= 1.6m
Height of next LW above CD	= 0.6m
Drop to next LW	= 1.0m
Depth of water at 1130hrs	= 3.8m
Clearance under keel	= 3.8 - 1.0 (drop to LW) - 1.5 (draught)
	= 1.3m clearance



Clearance under bridge	= charted height + (MHWS - height above CD at 1300hrs)
	= 13 + (3.5 - 1.8)
	= 13 + 1.7
	= 14.7
Mast height	= 12.5m above waterline
Clearance under bridge	= 14.7 - 12.5 = 2.2m

Interpolation chart