Module 3 – Nautical Science

Unit 5 – Physical Science

Chapter 23 – Sound and Sonar

Section 2 – The Doppler Shift

What You Will Learn to Do

Demonstrate an understanding of Physical Science

Objectives

1. Describe the Doppler shift
2. Explain the characteristics of sound in seawater
3. Describe sonar and its characteristics

Key Terms

CPS Key Term
Questions 1 - 8

Key Terms

Fathometer - A sonar instrument that uses echolocation to measure depths under water

Fish finder - A type of fathometer used by fishermen to locate schools of fish beneath their boat; the fish-finder screen displays water depth, echoes returned from fish

Key Terms

Doppler effect -	A change in the frequency with which waves (as sound or light) from a given source reach an observer when the source and the observer are in motion with respect to each other so that the frequency increases or decreases according to the speed at which the distance is decreasing or increasing

Key Terms

Doppler shift - The change between the highest and lowest frequencies heard and the source frequency is called the Doppler shift; it can be used to determine the speed and direction of motion of a sound's source, such as a submarine in the ocean

Hydrophone - An instrument for listening to sound transmitted through water

Key Terms

Active sonar -	The transmission of underwater sound pulses that strike targets and return in the form of echoes
Passive sonar -	Receive-only mode of operation to receive noise transmitted or caused by targets
Sonobuoy -	A buoy equipped for detecting underwater sounds and transmitting them by radio

Opening Question

Discuss and explain the Doppler Shift.

1.

2.

3.

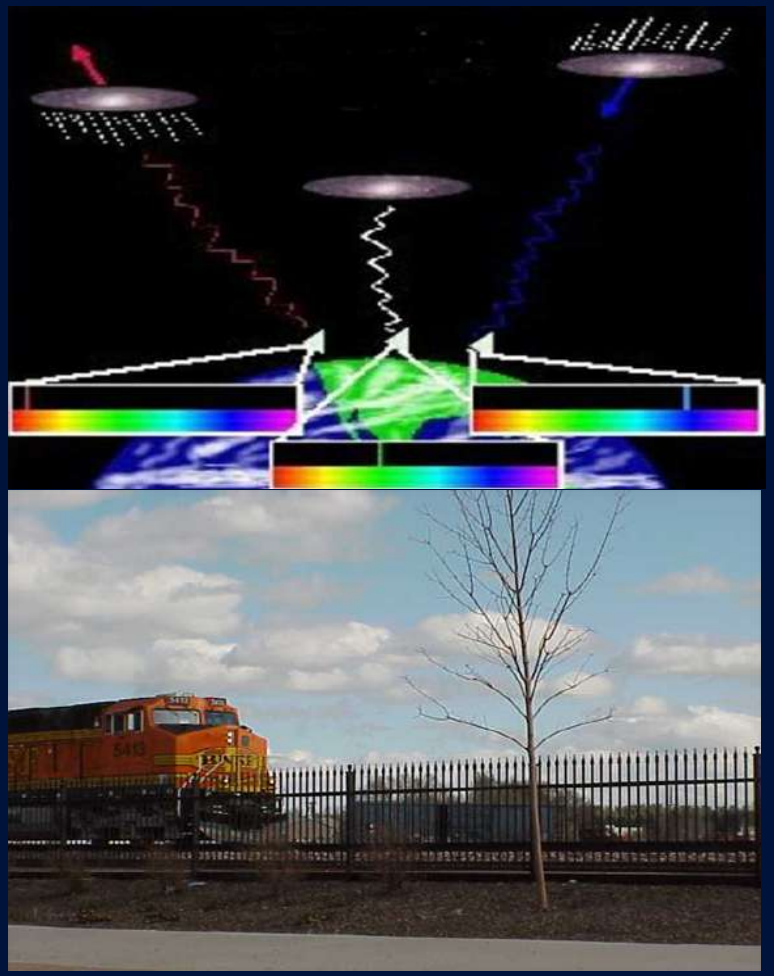
(Use CPS "Pick a Student" for this question.)

Warm Up Questions

CPS Lesson
Questions 1 - 2

The Doppler Shift

You may have noticed the apparent change in frequency or pitch of a train whistle or automobile horn as the train or auto approaches, passes, and departs.



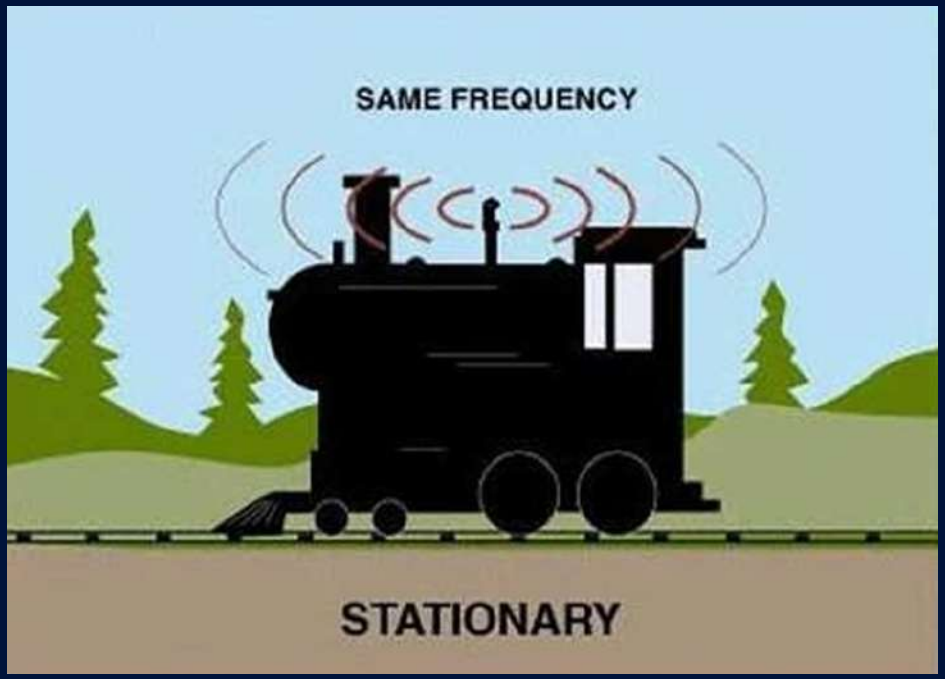
The Doppler Shift

In fact, there is no change in the frequency emitted by the source.

There is, however, a change in the frequency reaching the ear, because of the relative motion between the source and you.

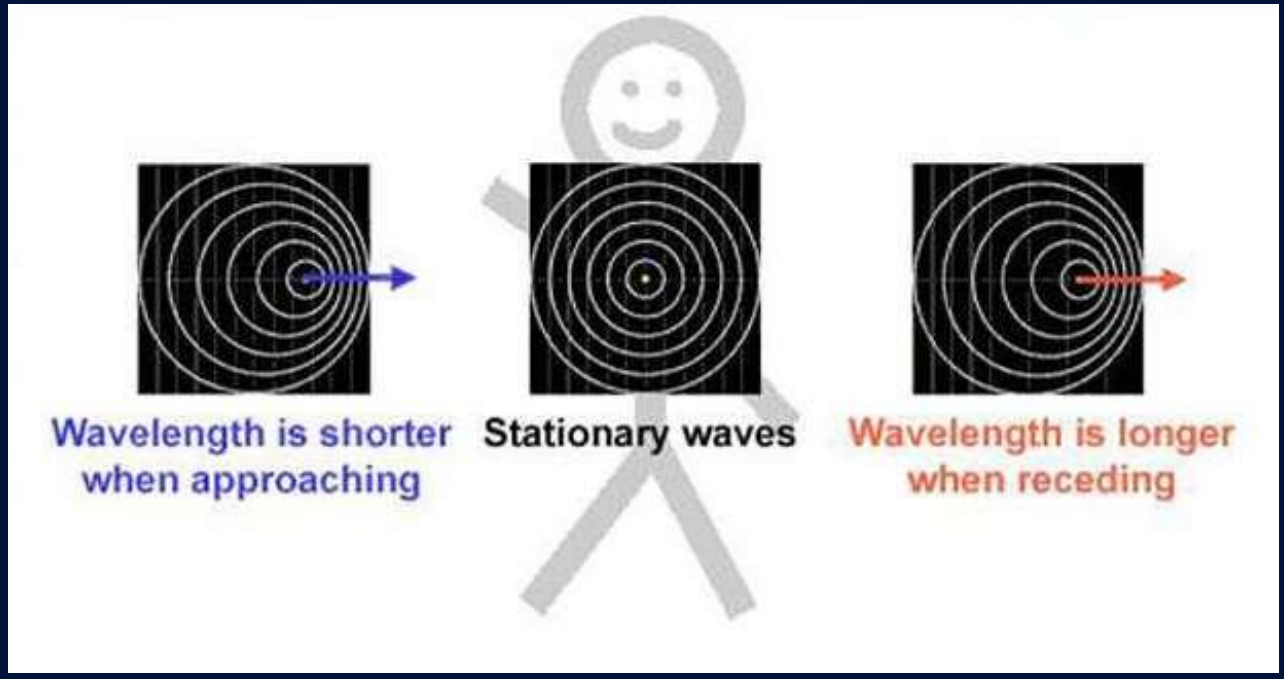
The Doppler Shift

As the train or auto approaches or moves closer, the effect is an increase in frequency caused by compression of the distance between waves.



When the source is opposite you, you hear the same frequency as the whistle or horn puts out.

The Doppler Shift



When the train or auto moves away, the effect is to increase the distance between waves, thus causing a decrease in the frequency reaching your ear.

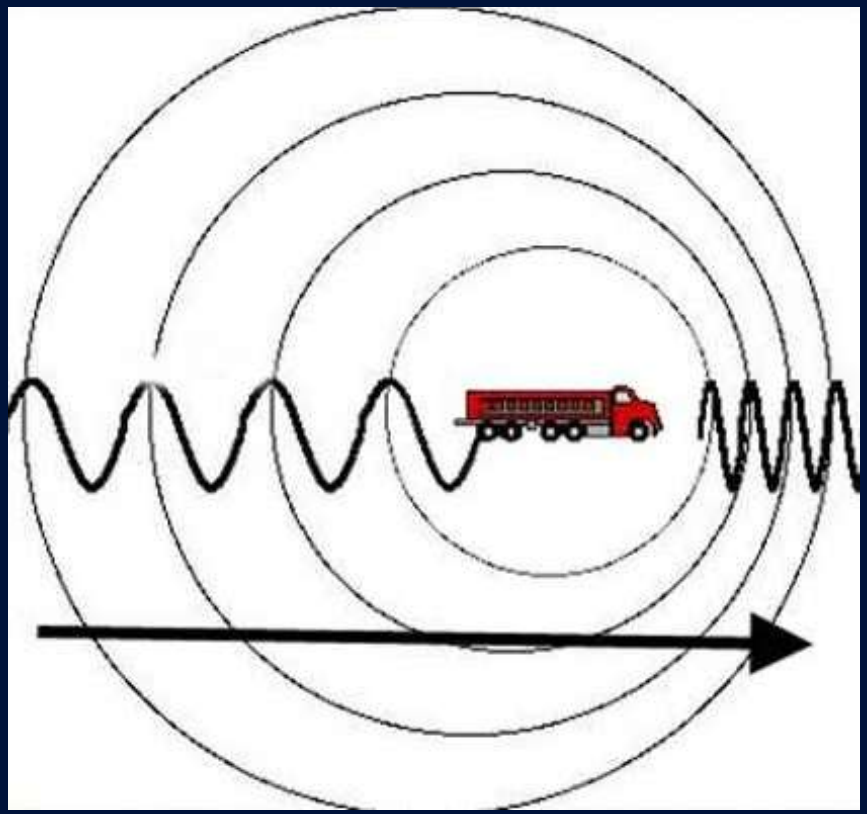
The Doppler Shift

The Doppler Shift

This phenomenon is known as the Doppler Effect, named for the Austrian physicist Christian Doppler.

Christian Doppler
(1803 – 1853)

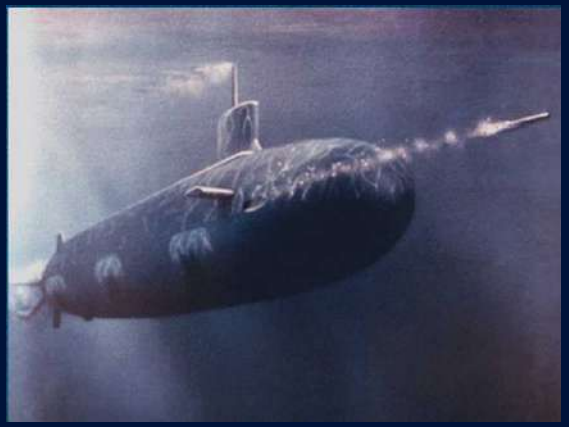
The Doppler Shift

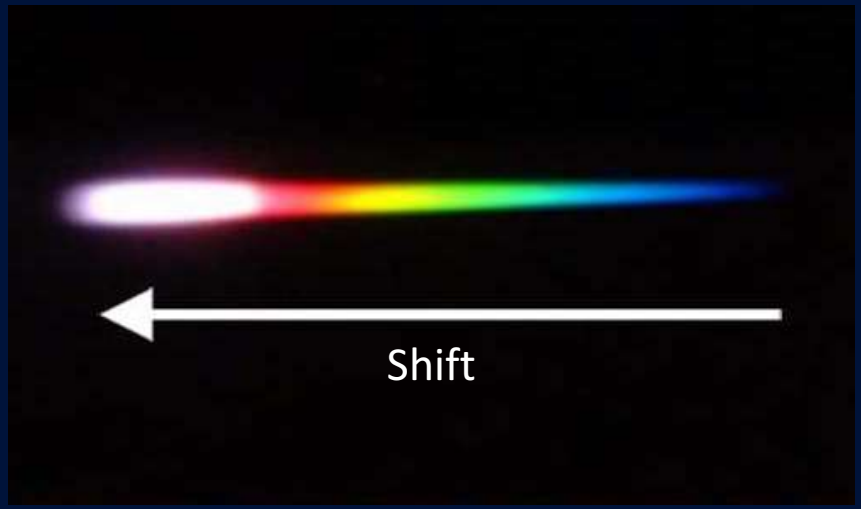


The total change between the highest and lowest frequencies heard and the source frequency is called the Doppler shift.

The Doppler Shift

The Doppler shift can be used to determine the speed and direction of motion of a sound's source, such as a submarine in the ocean.





Doppler shifts also occur with electromagnetic waves such as radio and light.

The Doppler Shift

By analyzing the Doppler shift in light from a distant star, for instance, astronomers can determine its speed and distance from us.

Radar detectors use the Doppler shift to determine the speed of baseballs and automobiles.

Sound in the Sea

Since Navy ships and submarines operate in the sea, the characteristics of sound in seawater are of special interest to the Navy.

Sound in the Sea

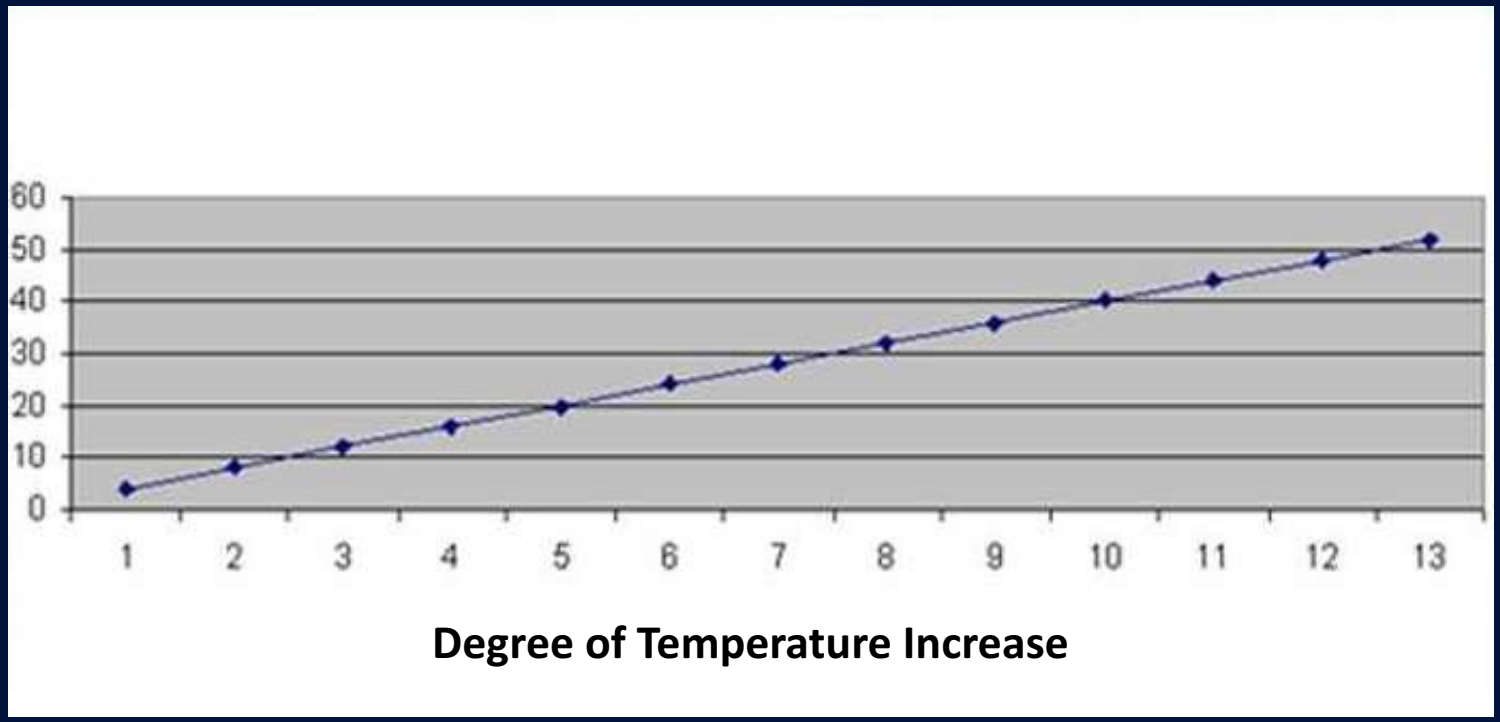
The speed of sound waves traveling through the water is affected by three conditions of seawater:

- Temperature
- Pressure, a function of depth
- Salinity, or salt content

Sound in the Sea

Temperature is by far the most important of the factors affecting the speed of sound in seawater.

Sound in the Sea



The speed of sound changes from 4 to 8 feet per second for every degree of temperature change.

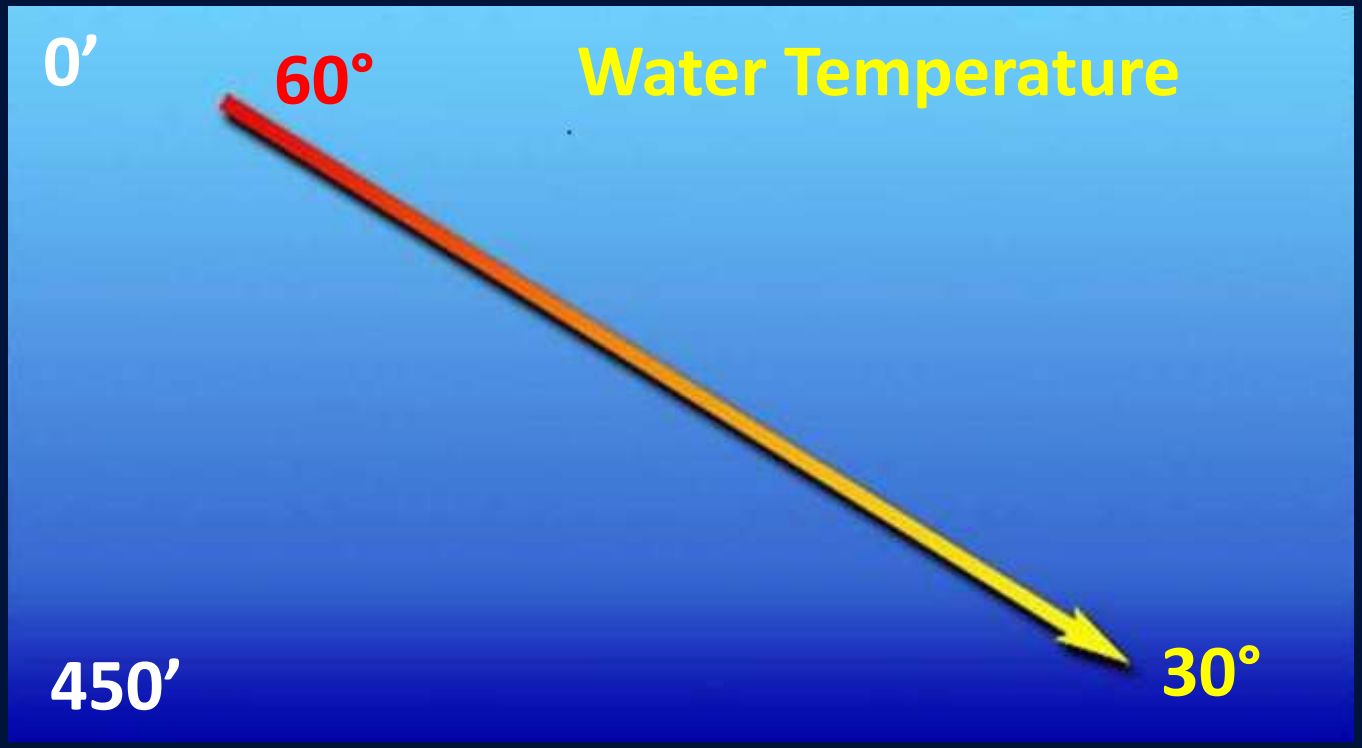
Sound in the Sea

The temperature of the sea varies from freezing in the polar seas to more than 85 °F in the tropics.

Check on Learning Questions

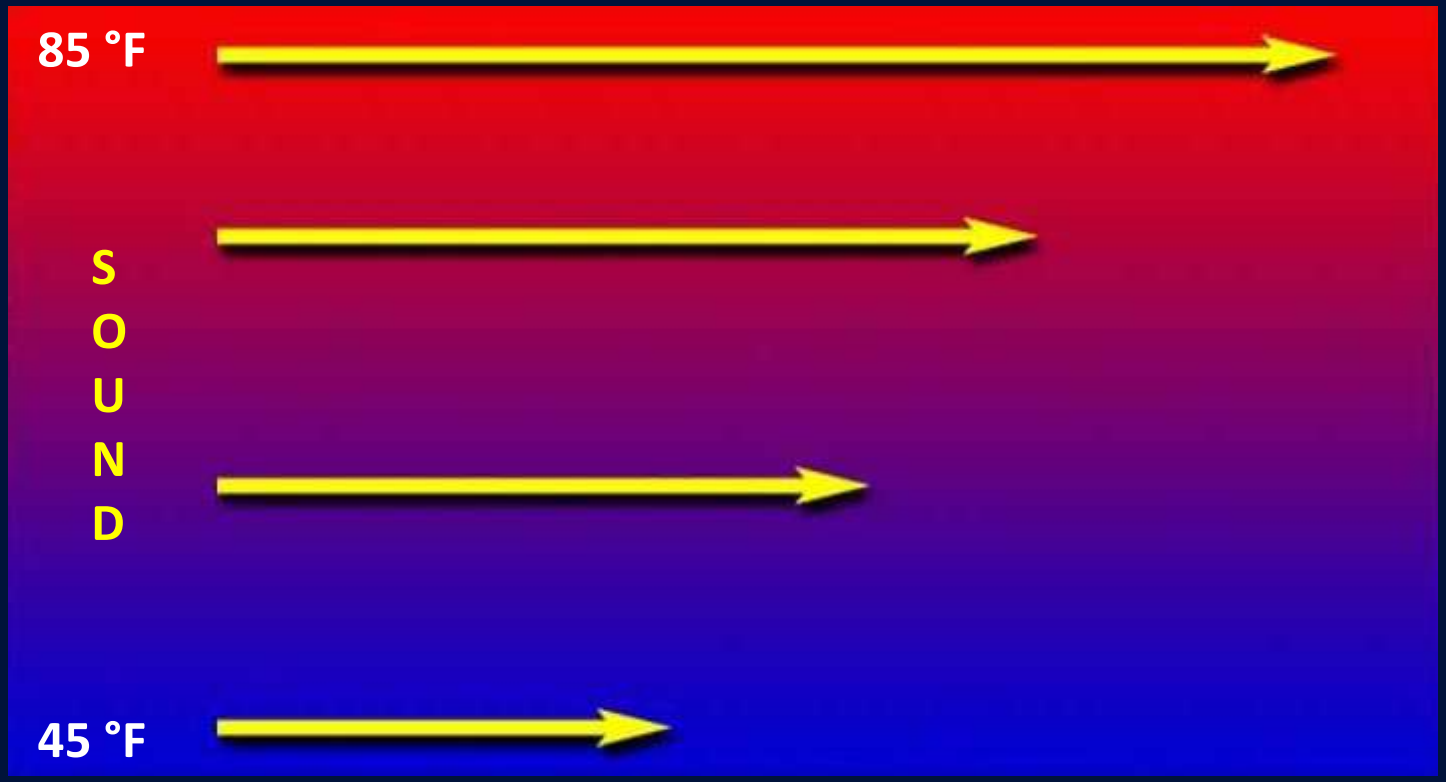
CPS Lesson
Questions 3 - 4

Sound in the Sea



Temperature may decrease by more than 30° from the surface to a depth of 450 feet.

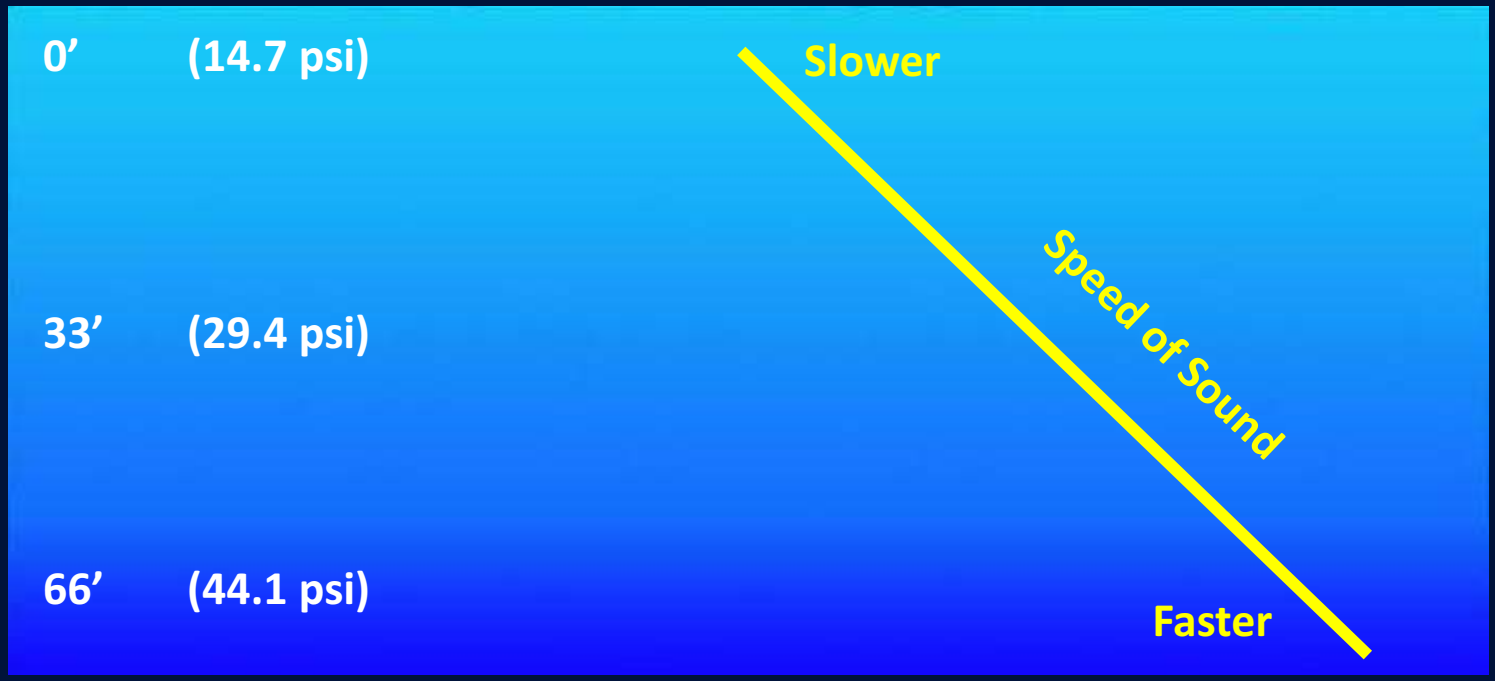
Sound in the Sea



Temperature changes in the sea have a great effect on the speed of sound in the seawater.

Sound in the Sea

Effect of Pressure on Sound Travel in Water



Pressure increases as depth increases, so the deeper a sound wave is, the faster it travels.

Sound in the Sea

Seawater has high mineral content or salinity.

Sound in the Sea

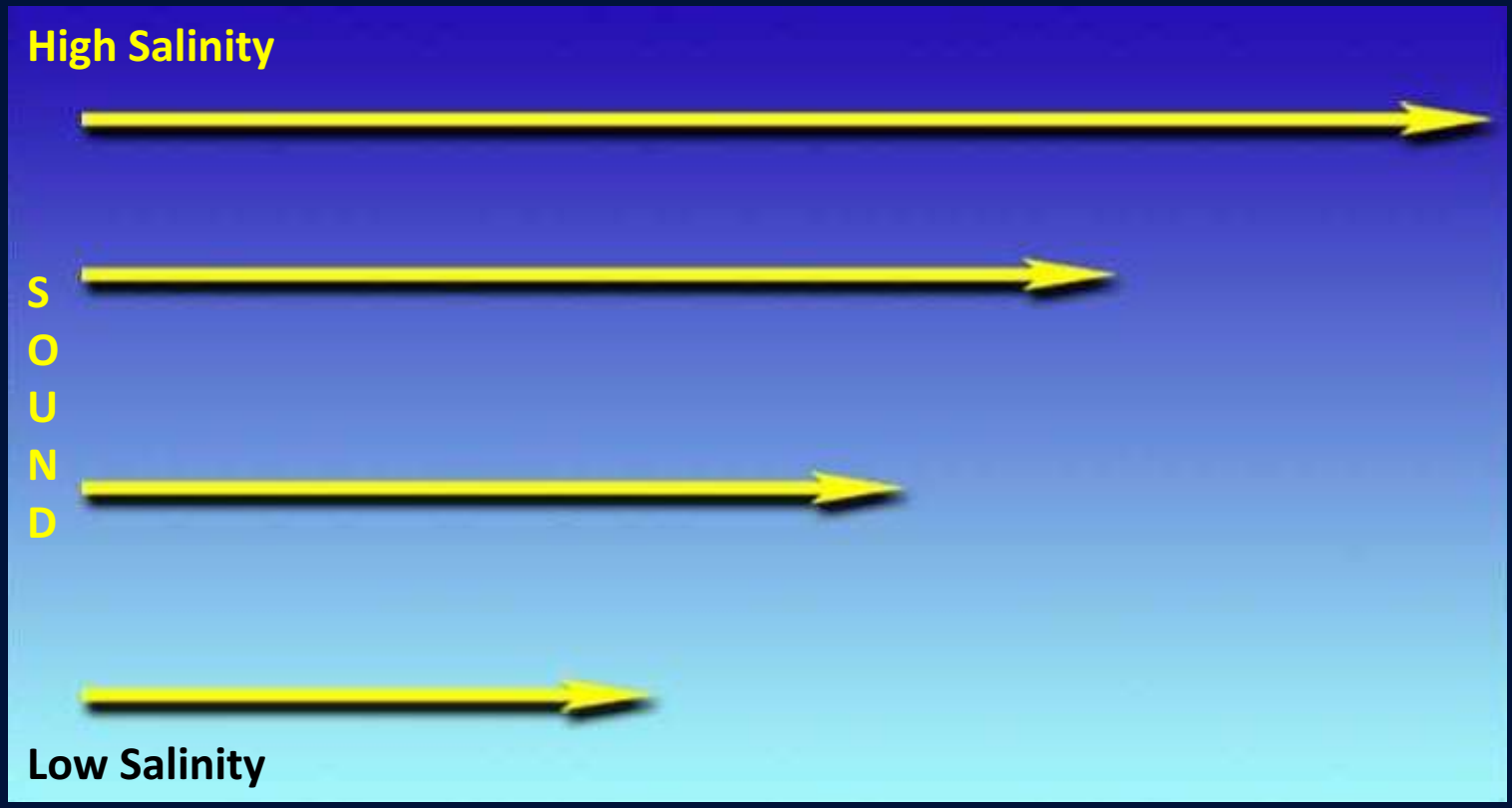
Density

Seawater = 64 lbs per cubic foot

Freshwater = 62.4 lbs per cubic foot

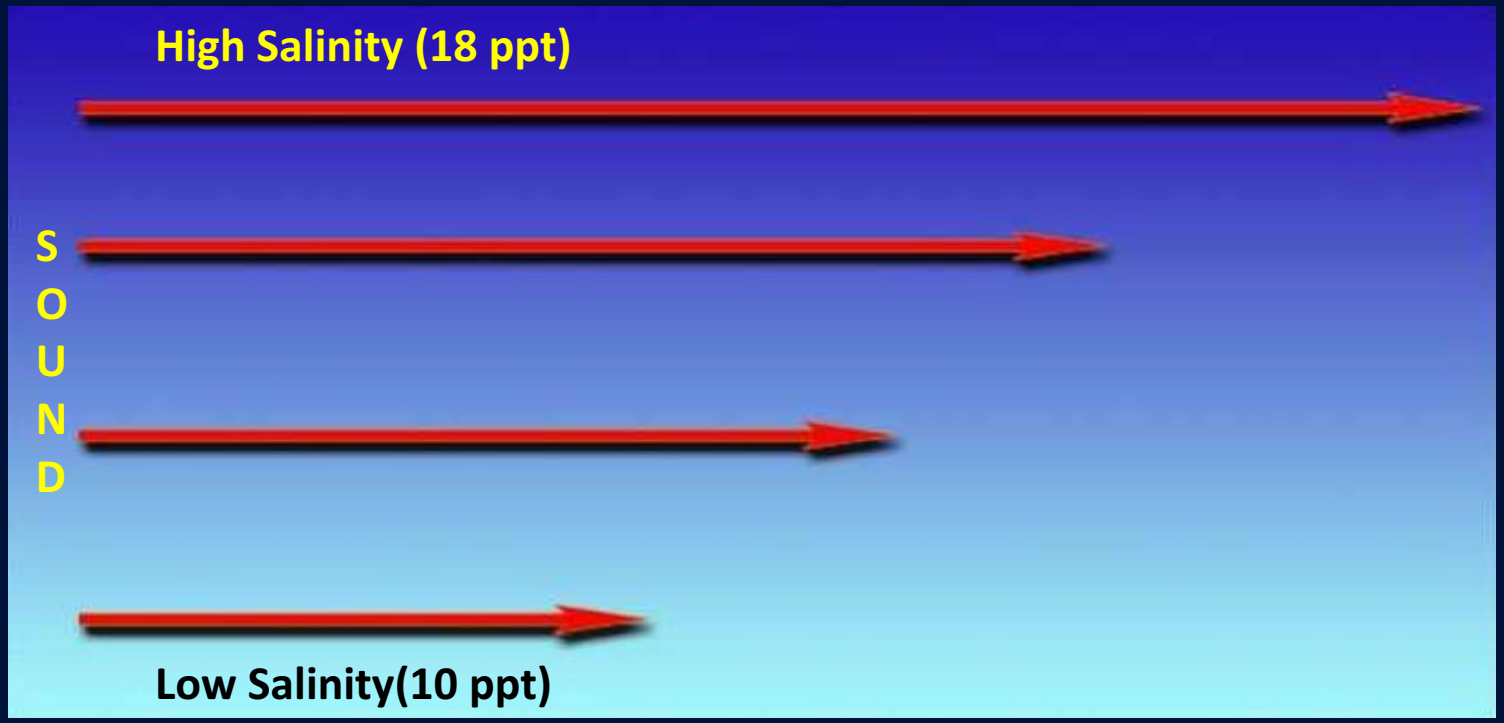
The density of seawater (due to salt content) is about 64 pounds per cubic foot; that of fresh water is only about 62.4 pounds per cubic foot.

Sound in the Sea



The saltier the water, the greater its density, and hence the faster the speed of sound in it.

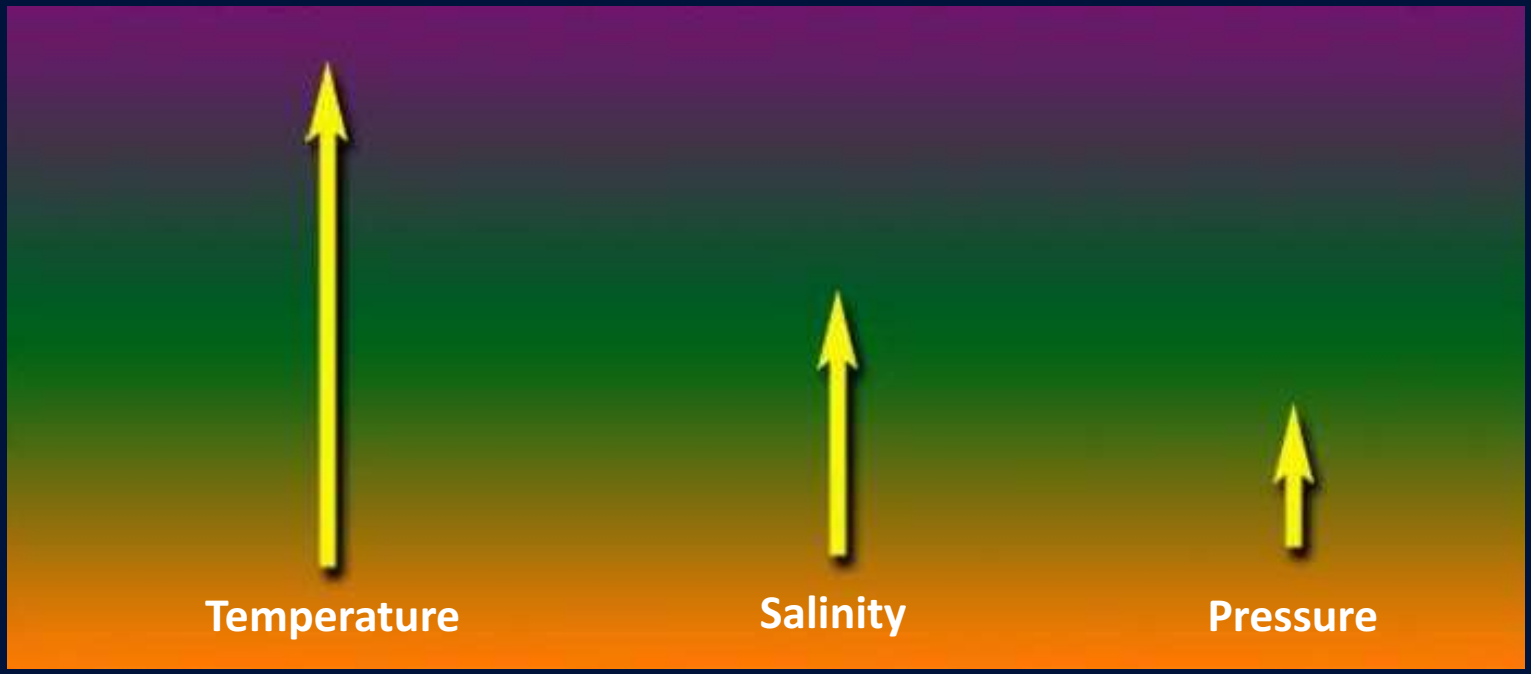
Sound in the Sea



The speed of sound increases about 4 feet per second for each part-per-thousand increase in salinity.

Sound in the Sea

Effect on Sound Travel in Water



Salinity has a lesser effect than that of temperature, but greater than that of pressure.

Sonar

SOund Navigation And Ranging

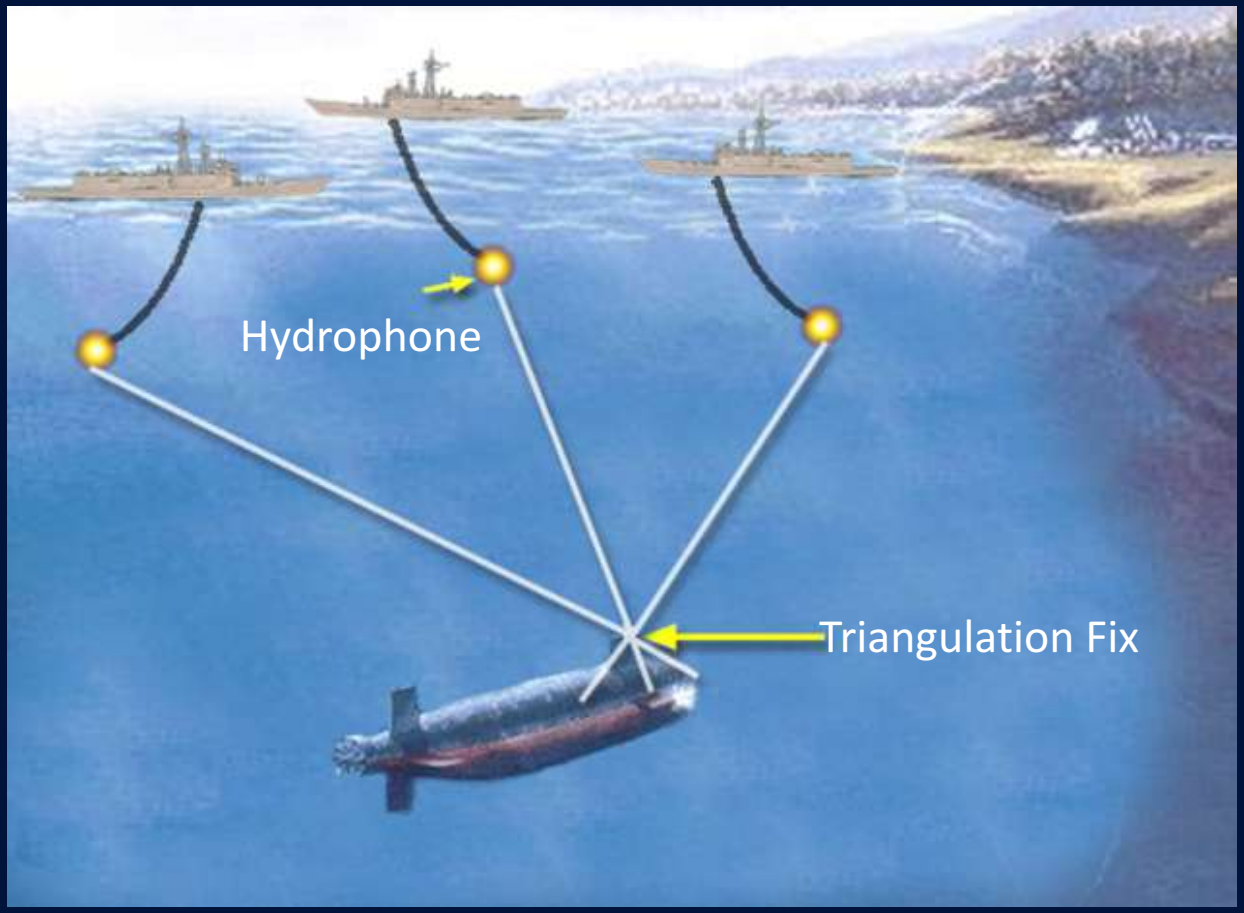
The principal means of detecting and tracking submarines at sea is called SONAR.

Sonar

The earliest sonar device, used in WW I, was a hydrophone lowered into the water to listen for submarines.

Sonar

Three hydrophones could pinpoint the location of a submarine by triangulation.

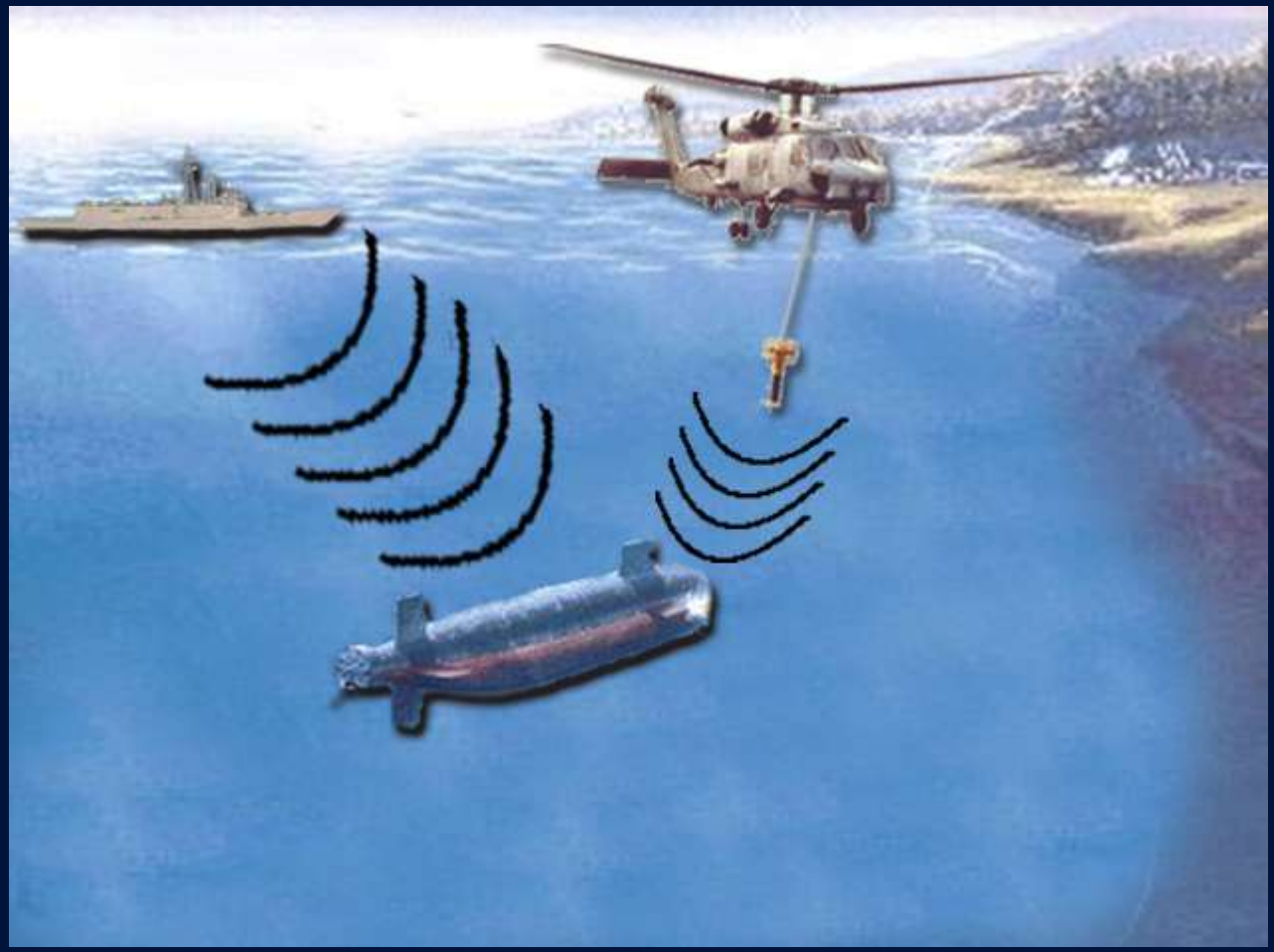


Sonar

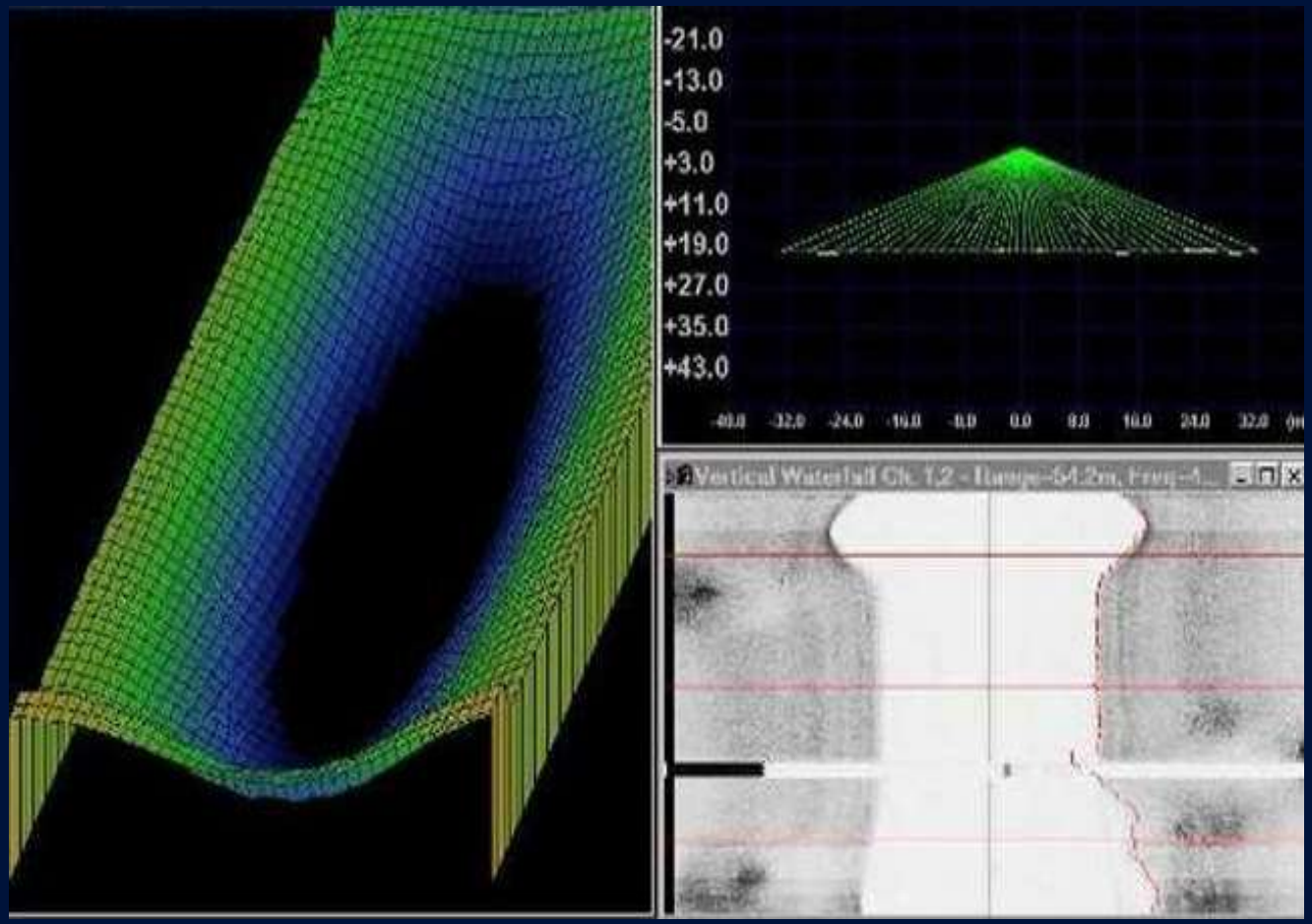
Today's sophisticated sonar equipment can provide highly accurate ranges and bearings to submerged submarines.

Sonar

Analysis of Doppler data provides accurate course and speed for a submarine.



Sonar



Sonar information is normally presented visually on a CRT screen rather than by sound, as the early devices did.

Check on Learning Questions

CPS Lesson
Questions 5 - 6

Sonar

Sophisticated sonar equipment for use by helicopters and fixed-wing aircraft have also been developed.

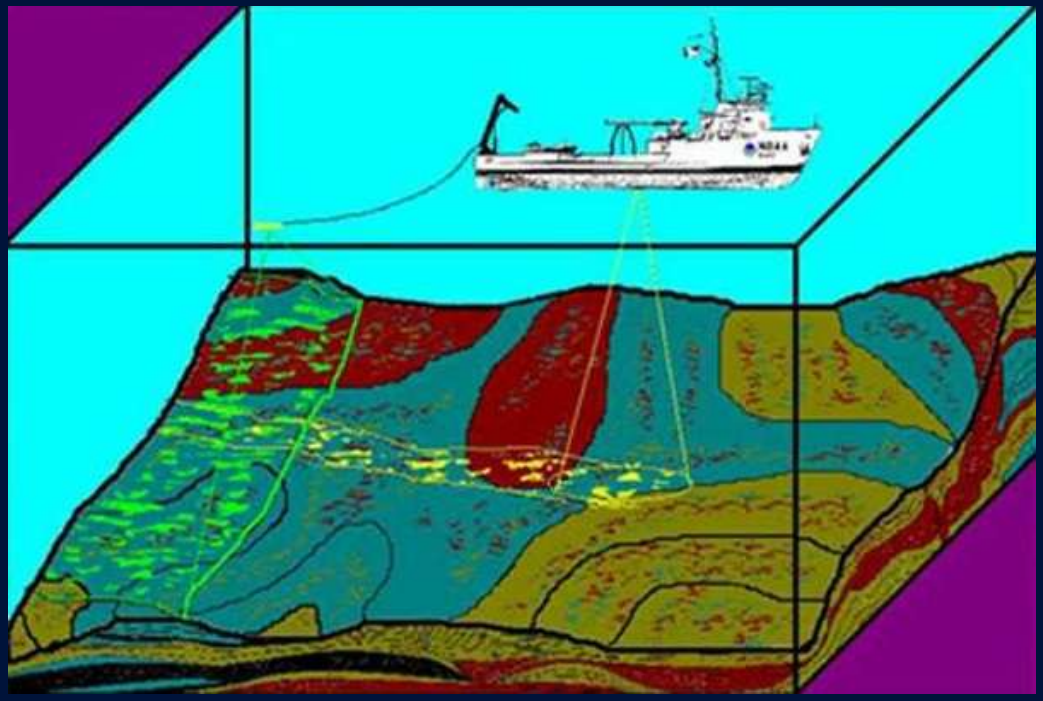
Two basic modes of operation for sonar systems can be used to detect targets. They are • Active and • Passive

Sonar

The returned echoes from active sonar indicate the range and bearing of the target.

When seeking out submarines, ships usually employ the active (pinging) mode.

Sonar



Active sonar is also used by submarines and ships to analyze shorelines, bottom characteristics, and ocean depths.

Sonar

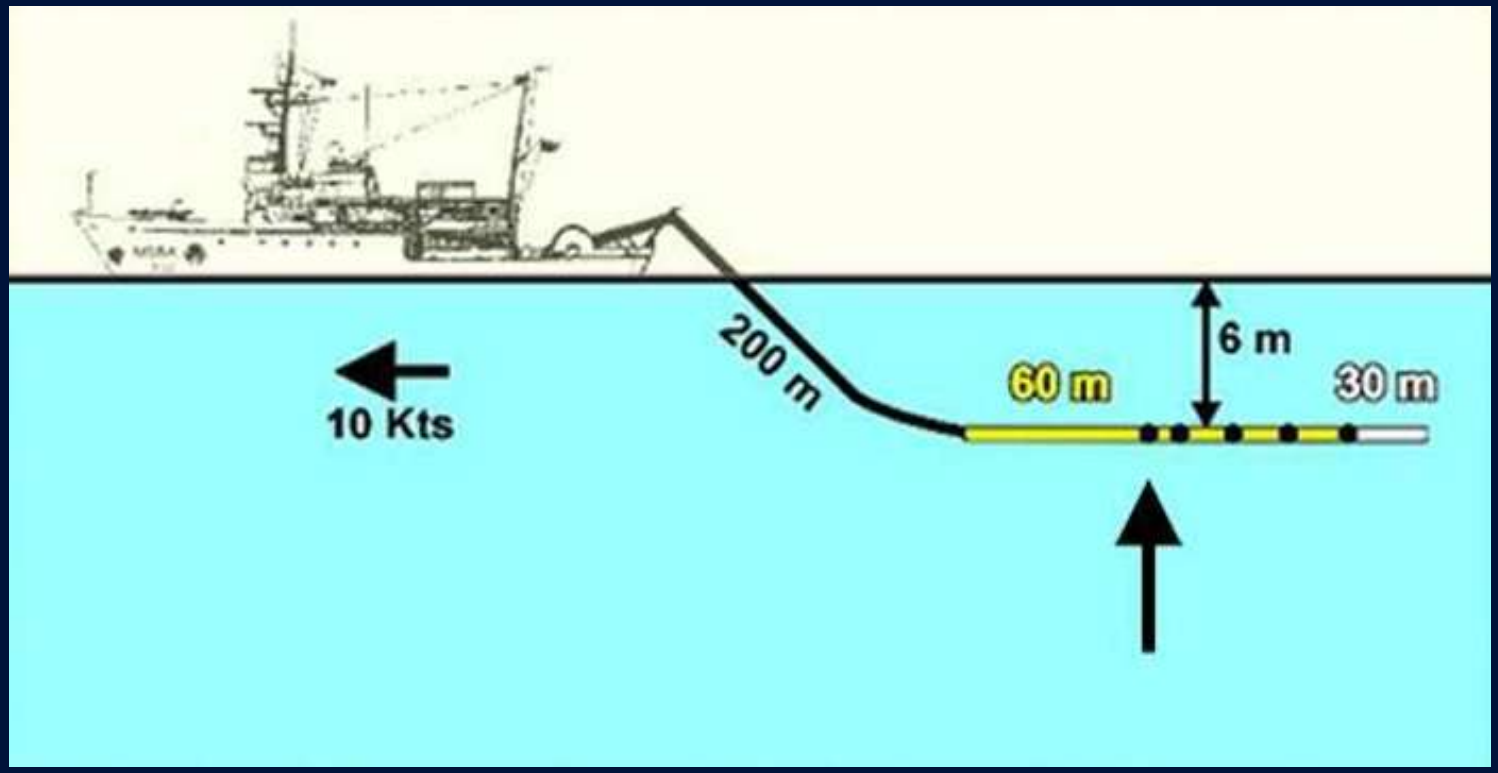
Although submarines can use active sonar, they rarely do to avoid revealing their position.

Passive sonars do not transmit sound.

Sonar

Passive sonars listen for sounds produced by the target to obtain accurate bearing and estimated range information.

Sonar



Target detection is achieved at great ranges through the use of highly sensitive hydrophones.

Sonar

The passive sonar mode is most often used by submarines, although surface ships also have the capability.

Sonar

Submarines use passive sonar to analyze the noise of passing ships.

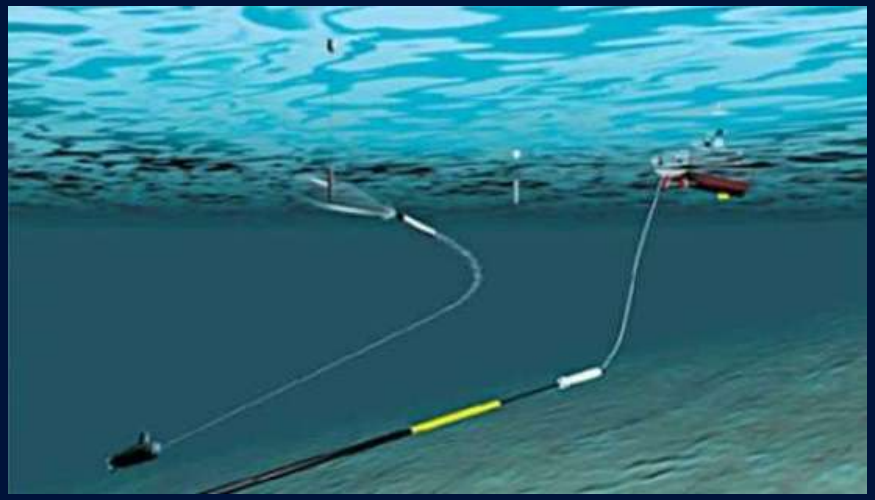
Undersea Warfare (USW) aircraft, helicopters, and shore stations also use passive sonar.

Sonar

Some sonar systems are mounted in domes below the ship's bow.

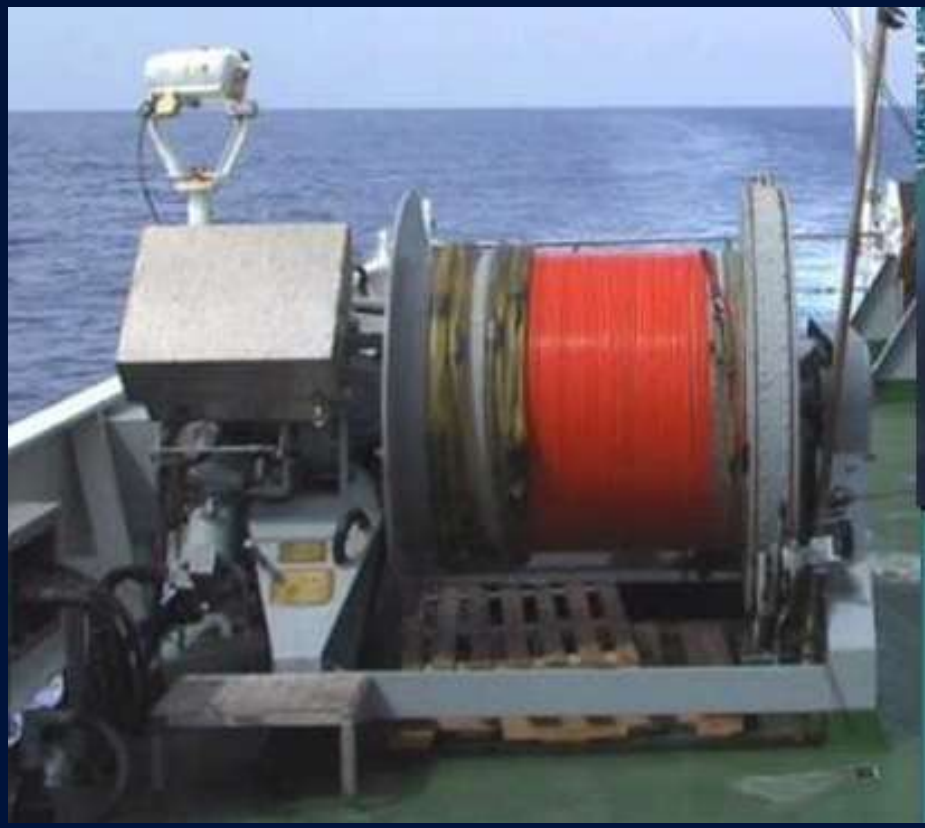
Sonar

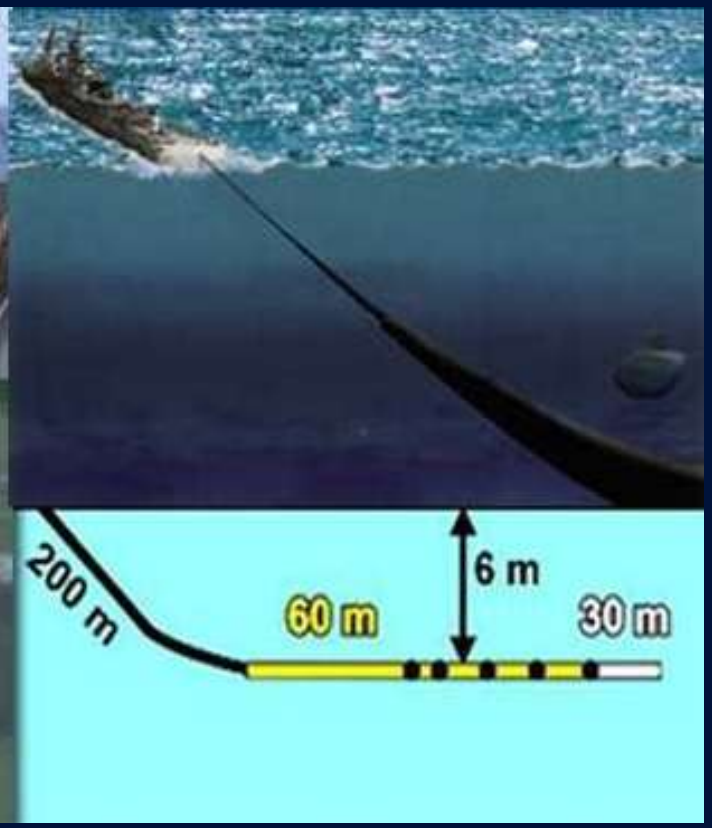
Passive sonar systems, called a towed array, are used on USW surface ships and submarines.



A towed array consists of a semi-buoyant tube several thousand feet or more long fitted with numerous hydrophones.

Sonar

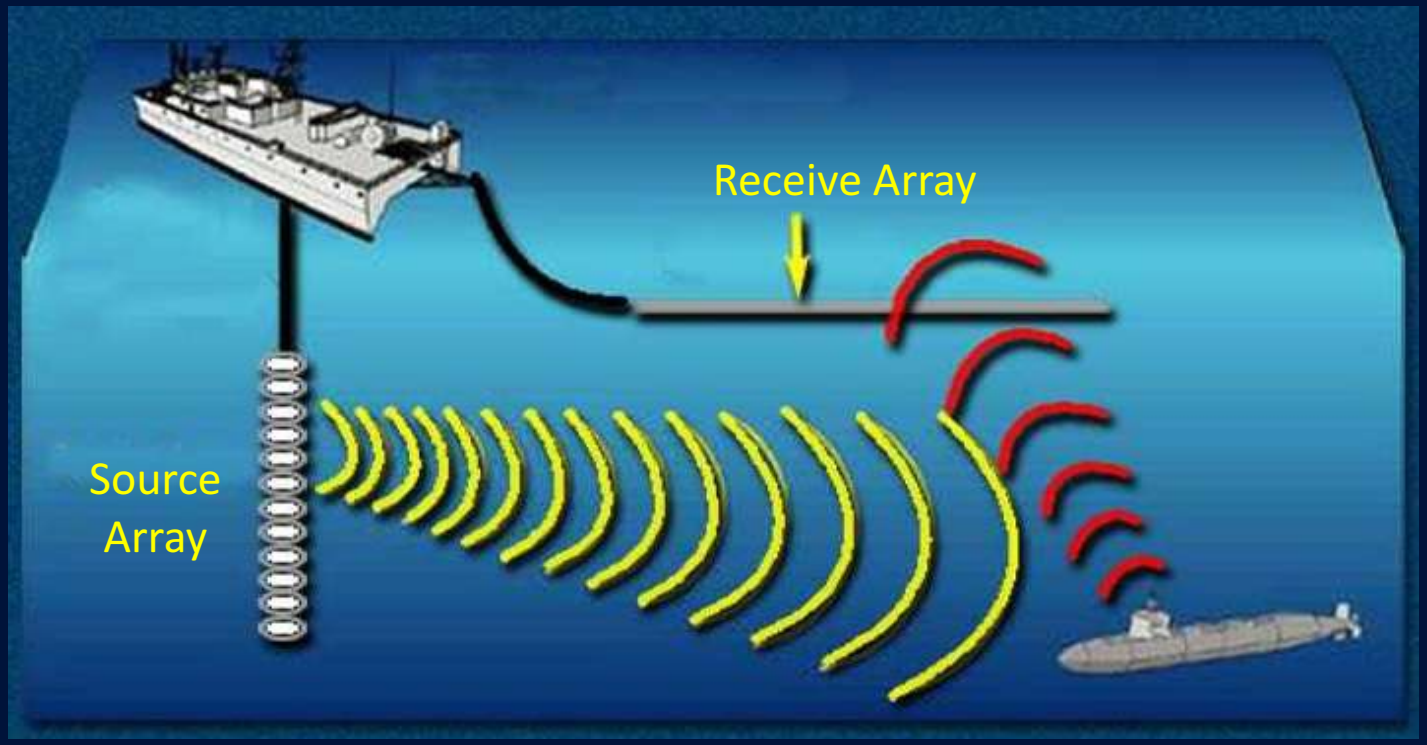




The array is unreeled and towed behind the ship.

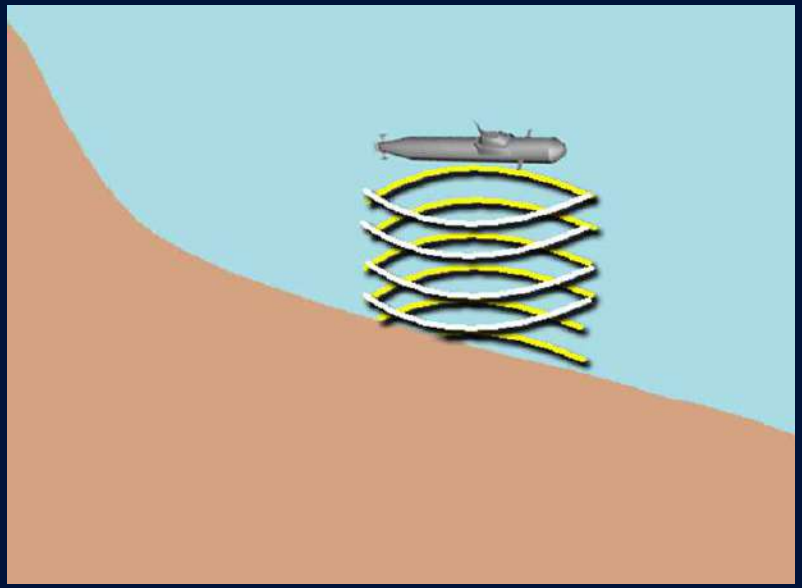
Sonar

A towed array is extremely sensitive and can pick up noise generated by submarines operating many miles away.



Sonar

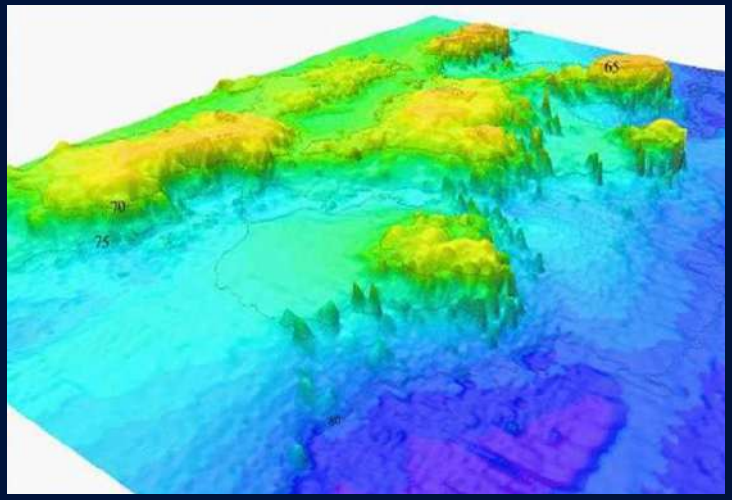
Most ships also have a fathometer installed to determine water depth under the hull.



A sound pulse is transmitted by the fathometer toward the bottom, and its echo is received back.

Sonar

The fathometer is normally used as a navigational aid, particularly when entering shallow water.

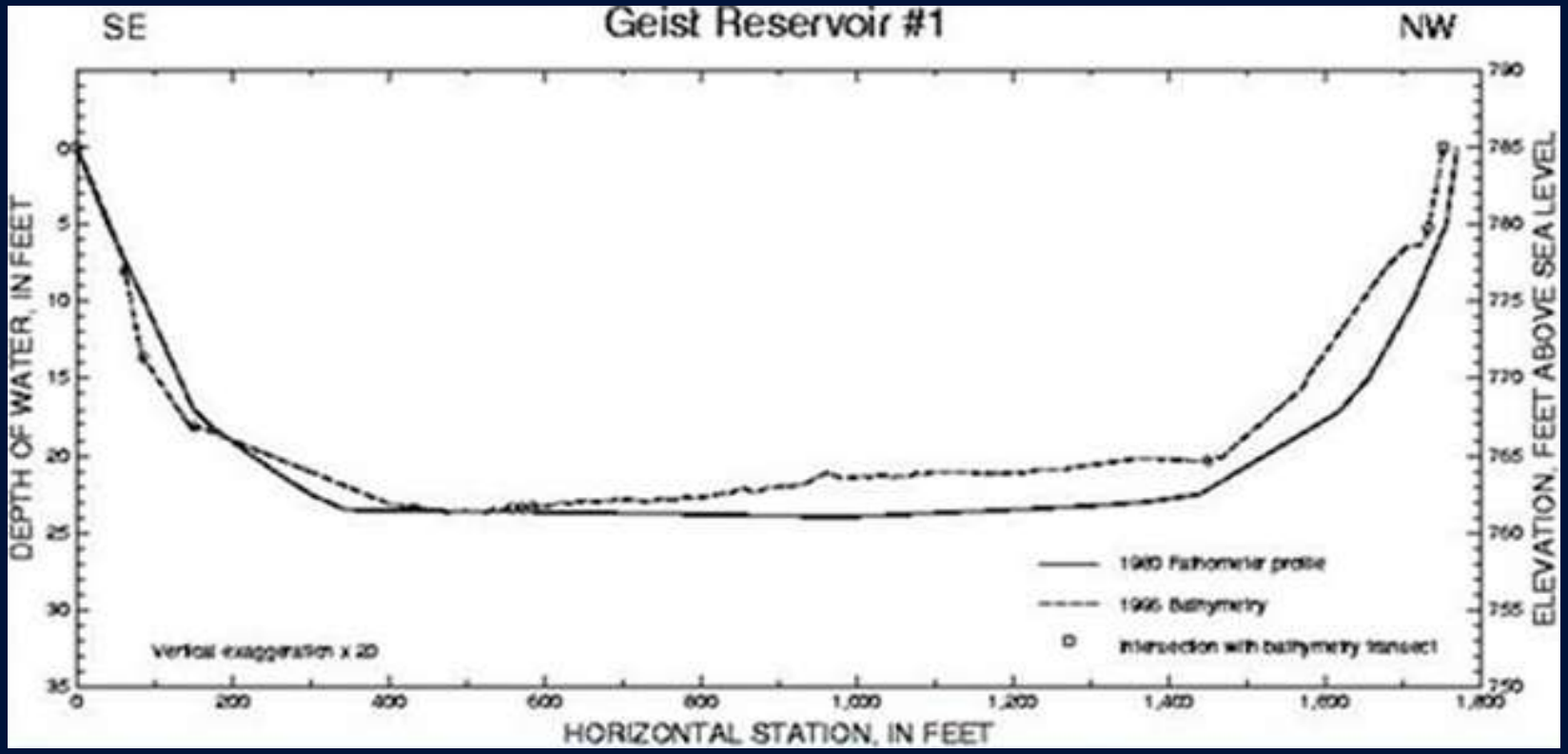


A fathometer is also used regularly in oceanographic research to determine the contour of the sea bottom.

Sonar

Most Navy ships keep their fathometer on continuously to have an accurate recording of the water depths on their course.

Sonar



The fathometer data can be displayed numerically or automatically recorded on paper.

Sonar

Dipping Sonar and Sonobuoys

Sonar equipment called dipping sonar can be used by helicopters to detect submerged submarines.

Sonar

The helicopter can hover and lower a hydrophone or pinging transducer into the sea to a depth of about 400 feet.

Sonar

The sonar searches a 360° area. After searching, the helicopter hauls in the cable and goes to another spot quickly.

When a submarine is detected, the helicopter can attack it with homing torpedoes or bring in other USW units to assist.

Sonar

Radio sonobuoys are small, expendable floating hydrophone units that are dropped by aircraft in the area of a suspected submarine.

Sonobuoys are usually dropped one at a time in a circular pattern around the contact area.

Sonar

By analyzing the radio signals received from each sonobuoy, the location and direction of movement of the submarine can be determined.

The target can then be attacked by the aircraft itself or by other available USW forces.

Review Question

Name and discuss three factors can affect the speed of sound in water.

1.

2.

3.

(Use CPS "Pick a Student" for this question.)

Closing Questions

CPS Lesson
Questions 7 - 8

Questions?