SAN FRANCISCO MARITIME
NATIONAL PARK ASSOCIATION

Submarine School

Where History Meets Science

Day Program Teacher's Guide

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Part I

ABOUT THE PROGRAM

INTRODUCTION

The World War II submarine USS *Pampanito* (SS-383) offers students and their teachers a unique glimpse into America's past. Walking the decks of this submarine brings history to life. Recognized as a National Historic Landmark, the USS *Pampanito* has helped instructors interpret the events of World War II to their students in a memorable way that books alone cannot.

But that's not all. A submarine is a most unique sort of vessel. The *Pampanito* was designed for a very special purpose: to travel on long patrols independent of support from other naval vessels and carry a large crew to operate her varied and complicated equipment in often hostile environments--and to do it submerged part of the time! To accomplish this, the submarine's designers had to answer a variety of questions, such as how to make the submarine dive, how to propel it, how to navigate, how to make its weapons operate, how to communicate inside the boat and out. How could they make the submarine do all these things and at the same time make it habitable and as comfortable as possible for its crew? The answers to these basic questions lay in the realm of science.

Science was used to address virtually all the design challenges submarine builders faced. In this way, the USS *Pampanito* presents teachers and their students an unusual platform for the study of a variety of topics spanning the physical sciences: Force & Motion, Electricity & Magnetism, Energy, Light, and Sound. In fact, most of these topics can be directly correlated with content outlined in the Next Generation Science Standards.

In the following curriculum, we'll examine some of these topics as they relate to submarine operation. The activities presented here only begin to scratch the surface of how submarine systems can be used as a means of teaching physical science. However, these lessons are essential to providing your students with the skills necessary to master the *Pampanito* Submarine School program. Teachers are encouraged to add supplemental activities to enhance their students' experience. A resource list of websites, books, and other materials is included in the Appendix.

OBJECTIVES

Students will:

- Explore practical applications of scientific concepts using an interdisciplinary approach.
- Develop specific science skills
- Develop teamwork and social skills

OUTLINE OF SCIENCE ACTIVITIES

Stations:

- Optics & Sonar- Learn about mirrors & make a periscope; explore principals of active and passive sonar
- Buoyancy - Learn why a boat floats and how submarines dive – experiment with a min sub
- Chemistry - Create a chemical battery and use it
- Sonar - Principles of passive and active sonar are explored here
- Code and Navigation - Decipher patrol orders from code and plot a course on map
- On-Board Pampanito – Guided tour of the vessel and the history of World War II

SCENARIO

Throughout the program, students onboard the USS *Pampanito* will rotate through 4 hands-on science stations. All the stations will have adult supervision, either by the teacher, adult chaperones, or our program staff. Because of its relative complexity, the Chemical Battery station will be operated by the science teacher (you!) It requires knowledge of how a battery works and the safe handling of chemicals. Our staff will facilitate the other 3 stations. Students are given individual notebooks (supplied by the *Pampanito*) in which to keep notes and track answers. The students will be acting in teams or crews during the activities. Although all notebooks will be turned in, each crew will designate one notebook to represent their team's work. At the end of the program, each student will receive a "Submarine Qualification" certificate. The crew with the best overall accuracy will receive an award at the end of the program.

POLICIES

Cancellations and Refunds:

- Your $600 deposit will be used towards the total cost of the program. Should you want to pre-pay for the program, please note that **no refunds will be offered for groups who pay for participants who do not show up**.
- Changing the date of your program **less than 60 days prior to the current program date will incur a $100 date-change fee**. Changes with more than 60 days' notice will not incur a penalty. **Cancellation of a program less than 60 days prior to the program date will hold the group responsible for the full cost of the program minimum**. Cancellation with more than 60 days' notice will not require full payment of the program minimum but will still forfeit the non-refundable deposit. Notice of cancellation must be made and acknowledged in writing.
- On very rare conditions, inclement weather may create hazardous conditions, requiring us to close the boat. In such cases every effort will be made to provide scheduled groups with advanced notice so that they can reschedule their visit, or if they choose, cancel altogether, and receive a full refund of their deposit. The San Francisco Maritime National Park Association will not be responsible for any other inconveniences or consequences arising from cancellation of a group's visit.

You are required to furnish the following:

- A current, valid insurance certificate. **(Important: The Certificate of Insurance should be in the amount of $1 million for bodily injury and property damage and should list the San Francisco Maritime National Park Association as an additional insured.)**
- Complete Medical and Liability forms for ALL participants. These are included in this packet and due on the day of the program.
- Signed acknowledgement of the Safety Procedures and Rules Of Conduct. This form is also located in this packet and due on the day of the program.
- Contract Terms and Conditions signed by the teacher and principal (or another administrator). This should be sent in by the contract due date.

No group may board the vessel until all these forms have been received. This manual provides more detailed information about our program and the aforementioned forms. You are responsible for reading it in advance of your visit. If you have any questions, please feel free to contact:

Education Director at (415) 740-2699 Email: ldefelice@maritime.org.

ACKNOWLEDGMENTS

The San Francisco Maritime National Park Association would like to express its appreciation to San Francisco Unified School District teachers Yvonne Chong, Marina Middle School, Cathy Christensen, A. P. Giannini Middle School, Debbie Farkas, Horace Mann Middle School, and Kevin Gortney, Presidio Middle School for their participation in the development of this program.

TRIP PLANNING AND LOGISTICS

GETTING READY:

Immediately upon receiving this packet….

- Confirm that the field trip date on your contract is the same as the date on your class calendar.
- Arrange transportation.
- Submit paperwork to the school district office.
- Arrange for insurance coverage for your field trip. (We require a Certificate of Insurance indicating a $1 million limit of liability for Bodily Injury and Property Damage, listing the San Francisco Maritime National Park Association as an additional insured (i.e., "Certificate holder is an additional insured.")

One month prior to your trip….

- Have a parent information meeting.
- Recruit your parent chaperones.
- Distribute medical forms to students and adults.
- Ensure that Insurance Certificate has been sent to our Education Office.
- Implement pre-visit activities.

One week prior to your trip….

- Collect medical/liability forms from students and adults.
- Meet with chaperones to go over program details.
- Make sure all participants bring a sack lunch
- Split class into 4 groups for the science station rotations.

24 hours to go…

- Confirm all medical forms have been collected.

When you arrive at Pier 45….

- Arrive at Pier 45 at 9:45 between sheds A & C and meet a member of our staff who will help you park vehicles (see map under Parking and Directions). **We have a 2-car maximum**; all other vehicles will have to find paid parking close by. All participants should arrive on foot to the Pier at 10:00am.
- Bring students and lunches to Pier 45 and line them up by crew. Teacher should bring payment, class list, and medical forms to the office while the students wait on the pier in a supervised and orderly manner.

Timeline of trip activities…

10 - 1015	Welcome Sub Rules	
1015 - 1035	Pier Tour	
1040 - 1100	Sub Tour	
1100 - 1150	Head Call & Lunch	
1150 - 1340	Four 25 min. Stations: Battery, Buoyancy, Navigation, Sonar, Periscopes	
	Rotation 1:	1150 - 1215
	Rotation 2:	1215 - 1240
	Rotation 3:	1240 - 1305
	Rotation 4:	1305 - 1330
	Allow 2- 3 minutes to rotate.	
1340 - 1400	Wrap Up & Goodbye	

Please keep in mind that this timeline is approximate and may vary according to each program.

PREPARING YOUR CREW :

Pre-training: Students will need certain skills prior to boarding the submarine. The lesson plans in Part II teaches these skills. If you have other lesson plans that teach the same goals and objectives, you may use them instead. Groups who cannot "pass" the pre-visit quiz will not be successful on the submarine.

Divide the class into crews (groups): Before you come on board, it is mandatory that you divide your class into **4 crews.** You know your class, so it is up to your discretion when assigning groups.

Crew Names: Each crew should choose an appropriate naval, maritime, or submarine related name.

Name Tags: Each person should wear a nametag. Crews will be provided colored arm bands as an effective way to keep crews together in the cramped confines of the submarine.

Rules of Conduct and Safety Rules: Participants are responsible for knowing and following our rules of conduct and safety. Complete rules are in this manual and the Acknowledgement must be signed by all attending adults.

WHAT TO BRING:

- **Payment:** Payment is due two weeks prior to the day of the program, in the form of one check. If your school needs to file a purchase order, it must be received early enough to allow the check to be ready **by the day of the program.**

- **Medical forms:** No child or adult will be allowed to board the submarine without a completed and legible medical form. Prior to the start of the program, a staff member will collect these.

- **Appropriate clothing:** Each participant should bring weather-appropriate clothing (rain gear and/or warm clothing). Please wear or bring a warm jacket and layers (the sub is warm inside, but days can be chilly on the pier). Comfortable, flat, rubber-soled, closed-toe shoes are recommended.

- **Cameras:** Only adults may use cameras during the program; students may take pictures after the science activities have been completed. ***Suggestion:*** Assign an adult chaperone to function as "Photographer's Mate" to take pictures during the science activities.

CONTRABAND (items not allowed aboard the boat):

- Radios, portable CD players, iPods, etc.
- Handheld electronics/gaming devices
- Cell phones---the teacher and adult chaperones may carry cell phones, but please keep them on silent or vibrate and refrain from using unless necessary. This will help ensure that everyone is actively participating in the program and that the safety of the students is being observed. Students are not allowed to have cell phones onboard.
- Alcoholic beverages and smoking are not permitted onboard.
- Food or chewing gum not permitted on submarine, water bottles only.

The San Francisco Maritime National Park Association is not responsible for any lost or stolen articles.

FOOD:

Please have students eat a snack either before leaving school or while en route to the boat as there will be no chance to eat until lunch at 11:30. All participants should bring a bag lunch for the day. Due to heightened nut allergies, no food with nuts (trail mix, peanut butter cookies, etc.) will be allowed on board. There is no refrigeration available, so be sure to bring a cooler if you have perishables.

Crews will eat on the pier or, if it's raining, will be shown to a sheltered space on the pier.

SANITARY FACILITIES (HEADS):

Our restroom facilities are extremely limited on the pier--there is one gender neutral restroom available, so head calls can take a long time. During lunch students can take shifts eating and using the head for the 35-minute lunch break. OR staff will decide to use the public restrooms located inside the pier shed; this will depend on cleanliness and safety on that given day.

USS *Pampanito* MAP & DIRECTIONS:

Pier 45 is located at the foot of Taylor Street and The Embarcadero –

Follow google Maps Link for Directions OR type in 45 Pier, San Francisco, CA 94133

Unfortunately, we do not have parking spaces available for the day program. All vehicles must find and pay for 4-hour parking nearby.

The San Francisco Maritime National Park Association is not responsible for damage or theft to vehicles. Please be aware of your surroundings, do not leave anything visible or of value in your vehicle, items may be stored securely in our education office.

SAFETY INFORMATION

To ensure your safety, as well as the well-being of the historic submarine, we ask that you please review the following information with the members of your group before your arrival.

Safe Conduct:

Please remember two important points about the USS *Pampanito*: First, *Pampanito* is a naval vessel which was intended to be operated by specially trained Navy personnel; Second, *Pampanito* is now a museum ship; both of these points dictate that safe conduct be exercised by each and every member of your group. Because of the design and construction of the submarine, special care must be taken while on board. Please adhere to the following:

- **Do not run while on board the submarine or on the pier.**
- Do not attempt to climb on the bridge deck without permission of staff.
- Step through watertight doors one leg at a time while holding on to the handgrip.
- Be aware of low overheads (low hanging equipment or fixtures) in the submarine---there are potential "head knockers" throughout the boat.
- While topside, always remain on the special walkway. Do not go outside the wire rope barriers at any time, or out on the bow or stern of the boat. The metal and wooden portions of the deck are usually wet and can be very slippery.
- When going up or down ladders, hold on to handrails with both hands.
- Stay out of any areas of the boat that are secured by locks or screws or are otherwise marked as off limits.
- Do not attempt to operate any equipment, turn switches, open any control panels or otherwise disturb any equipment on the submarine.

Safety Equipment:

- Telephone: a landline is in pier office.
- First Aid Kit: located in the office on the pier for emergency use or in the Education office
- Eye Wash Station: next to the building entrance.
- Life Rings: located on the pier and on the main deck of the submarine.
- Boat Hooks: located against wall in work area behind gangway.
- Life Jackets: on top of the Eye Wash Station.

Fire Emergency Procedure:

Smoke detectors are located on board. If an alarm sounds, please follow the protocol below:

- Exit the boat in a quick and orderly manner---no pushing and shoving---moving in the opposite direction of any smoke towards one of the marked exits.
- Do not close any watertight doors on the submarine.
- Inform staff immediately and call 911.

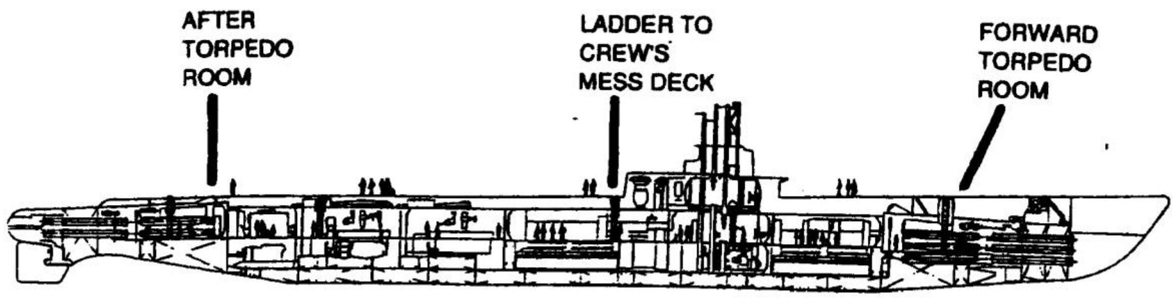
Emergency Phone Numbers:

- Ambulance/Fire/Rescue/Police: 911
- Local Police dispatch (emergency): (415) 553-8090
- Police (non-emergency): (415) 553-0123 or (415) 553-1532
- Poison Control: (415)476-6600

USS *PAMPANITO* Emergency Evacuation Plan:

In the event of an emergency, it may become necessary to evacuate the submarine. Staff will conduct an evacuation drill with your group to make certain everyone understands what steps to take. The diagram below shows the three main access points into and out of the submarine.

Exit the submarine through one of the following access ways:



Remember:

- Move in the opposite direction of any hazard.
- Use flashlights if necessary.
- Do not push or shove on your way out; walk in single file.
- Do not close any watertight doors.
- If access to both main exits (After Torpedo Room and Forward Torpedo Room) is blocked, you may use the ladder in the Crew's Mess (push aside grate at top of ladder).
- The first person out should notify staff of the problem immediately, and/or call 911 if necessary.
- The rest of the group should line up on the pier and the group leader should take a head count.
- Remain lined up on the pier and wait for further instructions from staff/emergency personnel.

<u>RULES OF CONDUCT FOR GROUPS ABOARD USS *PAMPANITO*</u>

To ensure a safe and pleasant visit, all USS *Pampanito* Program participants are required to abide by the following rules. Group leaders should distribute (or read aloud) the rules to the entire group prior to their visit.
Remember: **<u>Discipline is the responsibility of ALL ADULT chaperones, and a signed Rules of Conduct form is required from each adult over 18 years of age who will be present during your program.</u>**

1. Absolutely no running or horse play aboard the vessel or on the pier.

2. Adequate adult supervision is always required from the visiting group.

3. Do not enter restricted areas without permission of *Pampanito* staff. These areas are well marked. When topside, do not leave the marked walkway. Do not climb on any deck guns or on the periscope and lookout platforms.

4. Do not turn valves, switches, handles, or attempt to operate any equipment aboard the submarine.
<u>Everything on board the submarine is an historic artifact and must be treated with respect</u>.
Remember, USS *Pampanito* is a National Historic Landmark (just like the Washington Monument!)

5. None of the following are permitted:
   - Alcohol consumption during your visit, on or off premises
   - Smoking
   - Gum, sunflower seeds, or nuts with shells
   - Radios, portable audio devices, handheld electronics/gaming devices, laptop computers, etc.
   - Anything else listed in the Contraband Section of this manual

6. Teachers are to make sure all required paperwork is completed and submitted prior to boarding.

7. **The group must follow all directions and special instructions issued by members of our staff.** Doing so ensures the best possible program and a chance for your school to return!

ACKNOWLEDGEMENT OF SAFETY GUIDELINES AND RULES OF CONDUCT FOR GROUPS

→ (To be signed by all adult participants aged 18 and over) ←

I. the undersigned acknowledge the Rules of Conduct for Groups and Safety Rules for Groups. I have read these rules and agree to abide by them. I also certify that all participants under the age of 18 (if any) have been informed of these rules and I will assist in ensuring they are followed by all participants. Further, I understand that anyone violating these rules may be directed to leave the *PAMPANITO* and its Pier 45 spaces.

SIGNED: ____

PRINTED NAME: ____

DATE: ______________________________________

SAN FRANCISCO MARITIME NATIONAL PARK ASSOCIATION

PARTICIPATION AGREEMENT, ASSUMPTION OF RISK, AND LIABILITY WAIVER

→ (To be completed by Parent or Guardian of participants under the age of 18) ←

All participants in activity programs of the San Francisco Maritime National Park Association (the "Association") must agree to the provisions below. These programs may include boating and other potentially hazardous activities, all of which are at the sole risk of participants.

In consideration of my or my child's participation in Association programs, now or in the future, I agree on behalf of myself and my child to assume all risks of accident, injury (including death), or illness arising out of or in connection with participation in those programs. I further agree on behalf of myself and my child to forever waive and release all claims and causes of action against the Association (including its officers, trustees, employees, and agents) and the National Park Service, a Bureau of the U.S. Department of the Interior (including its officers, employees, and agents), for any and all liabilities for injury (including death), illness, or damages arising out of or in connection with participation in those programs. This assumption of risk and liability waiver shall bind the members of Participant's family and Participant's heirs, personal representatives, and assigns.

I understand that this is the sole and exclusive agreement with the Association regarding assumption of risk and liability waiver, that this agreement supersedes all prior or subsequent discussions, representations, or agreements about those subjects, and that this agreement may be modified or waived only by a writing signed by an officer of the Association that makes specific reference to this agreement.

Date of Program: ____________________ School: ______________________________________

Participant's Name: __________________________ Parent/Guardian's Name: ___________________________

A minor without a duly signed Release Form will not be allowed to participate in the program.

Signature of Parent/Guardian: ____

Date: _____________________________

==

SAN FRANCISCO MARITIME NATIONAL PARK ASSOCIATION

→ (To be completed by ALL participants) ←

Date of Program: ____________________ Group Name/School: ________________________________

Participant's Name: ____________________ ☐ Adult (over 18) ☐ Minor (under 18)

Address: ____

Emergency Contact Name: ________________________ Relationship: _______________________ _

Phone Number for Emergency Contact: _________________

Do you have any physical or medical conditions, restrictions, or special needs? If so, please describe:

____

Occasionally photographs of the program are used in publications. If you **do *not*** want photographs containing your image (or your child's) used in print or online, please indicate here: _____________________________

Signature of Participant ____ Date__________________

Signature of Parent/Guardian if under 18 ____

Part II LESSON PLANS AND ACTIVITIES

The following are in-class activities designed to help you prepare your class for participation in the *Pampanito* Submarine Science program. Feel free to substitute your own lessons if they have similar objectives.

LESSON 1: BUOYANCY

Time: 50 minutes **Goal: To gain an understanding of buoyancy**

Objectives: Students will be able to:

- Understand the concept of gravity
- Understand the concept of friction
- Understand the concept of gravity and friction as a force
- Understand how these forces effect buoyancy
- Understand what is meant by water displacement
- Design a hull that will maximize its ability to hold cargo

Background:

An object floats or sinks depending upon its ability to displace water. Increasing the volume (area that the object occupies) increases displacement. This increases the buoyancy, or the ability to float. Increasing the volume an object occupies increases its surface area, thus increases the friction it experiences as it moves. Thus, the shape of the object in liquid can serve two purposes: An object designed for speed must have the minimum displacement possible to decrease friction, i.e., a speed boat. An object designed to carry a heavy weight, such as a cargo ship, must be designed to maximize displacement, thus increasing buoyancy and friction.

Water in general is always striving to maintain a level surface. When you place a boat in water, gravity pulls it down and the water is displaced. The water is no longer level. You have two forces at work against the hull of the boat: the pressure of the water pushing up trying to regain a level plane and gravity pulling it down.

The hulls of boats are designed to transfer or spread out the force of the water over a larger area, thereby decreasing the force at any point. If the pressure of the water pushing on the hull is greater than the force of gravity pulling it down, then the boat floats! So, if you take a seaworthy boat hull, break it down and compress it together, and place it in the water, it will no longer float. Why? There is no longer sufficient water displacement to counteract gravity and the desire for the water to maintain a level plane.

Materials:

- Plastine modeling clay or foil
- Small metal nuts or paper clips
- Tub of water

Activity: Start by demonstrating that when the clay or foil is in the form of a ball it will sink. Discuss the concept of water displacement and buoyancy then give students the following challenges:

Challenge 1: Give each student a ball of clay or foil and challenge them to redesign the ball into a shape that will float. Have a contest to see which design will hold the most cargo (metal nuts or paper clips).

Challenge 2: Have the students think of what hull design would make a hull as frictionless as possible, which could be used as a "race boat"? Why?

Challenge 3: Introduce the concept of positive, neutral, and negative buoyancy. Have the students brainstorm why a submarine uses these three stages of buoyancy.

LESSON 2: LIGHT

Time: 50 minutes

Goal: To gain an understanding of how light is reflected.

Objectives: Students will:

- Position mirrors to see objects out of the direct line of sight
- Understand how the position and number of mirrors used will affect the appearance of an image

Background:

Light travels in a straight line unless it is modified or controlled by another object.

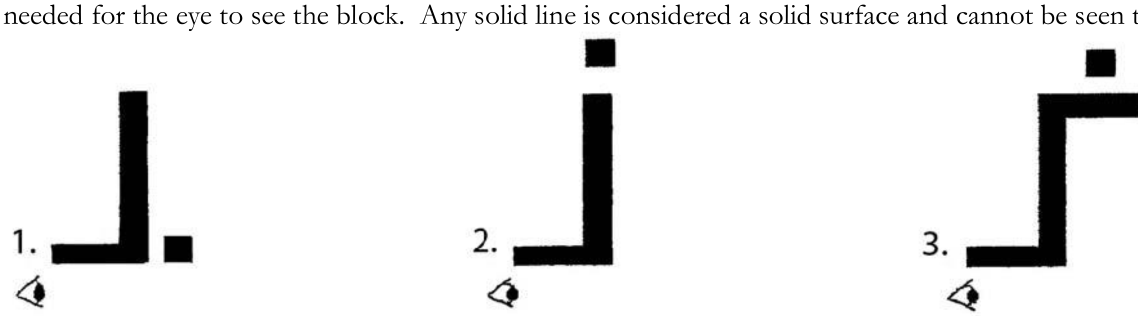
Light can be:

- **Blocked**, such as by a cloud or wall
- **Refracted** (bent) when it passes through another transparent material of a different density
- **Reflected**, in which its path is changed by a mirror

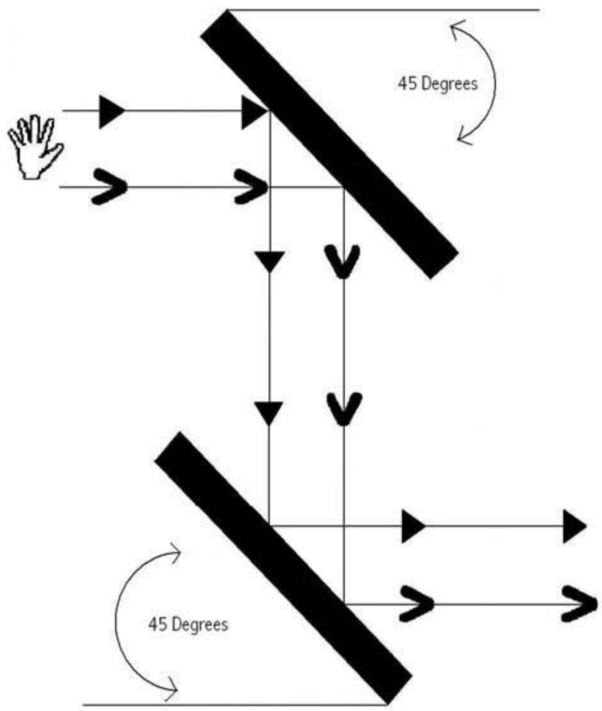
Note on Reflected Light: Light always reflects away from a mirror at the same angle that it hits the mirror. If light hits the mirror at a 10-degree angle it will be reflected at a 10 degree angle away from the mirror.

Activity:

1) Draw lines to represent the location of mirror(s) needed for the eye to see the block. Label the mirror angles needed for the eye to see the block. Any solid line is considered a solid surface and cannot be seen through.

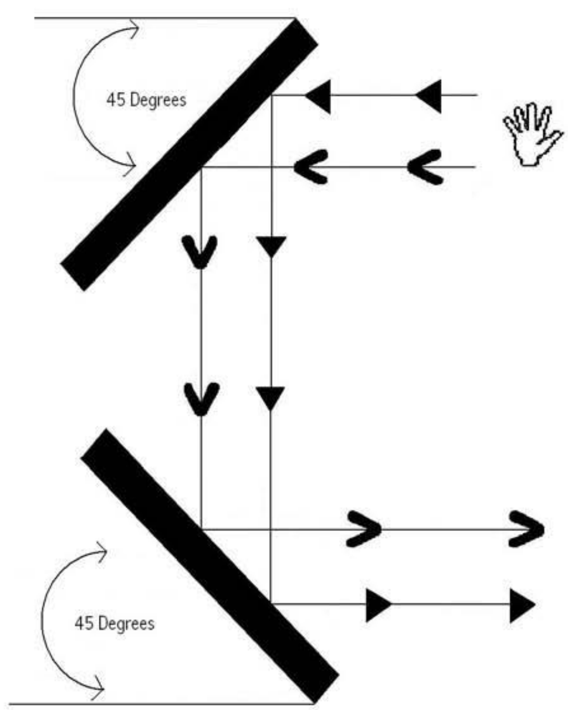


2) Because light travels in a straight line, the position and number of mirrors can change the appearance of the object being reflected. Complete the following exercise, paying close attention to the path of the light from mirror to mirror.



A.

Study the illustration to the left. Draw the hand, as it would appear to the viewer. Explain your answer.



B.

Study the second illustration here. Draw the hand, as it would appear to the viewer. Explain your answer.

LESSON 3: RAIL-FENCE CODE

Time: 100 minutes

Goal: To gain a working knowledge of the Rail-Fence code.

Objectives: Students will be able to:

- Translate messages into Rail-Fence code
- Decode messages written in Rail-Fence code

Background:

Rail-Fence code is a transposition code. Multiplication tables, such as 2 X 4 or 5 X 5, are the keys to this code. Using multiples of the total message letter count, the letters are regrouped to encode the message.

To encode a message using Rail-Fence code, first count how many letters are contained in the message.

Example: "A SLIP OF THE LIP CAN SINK A SHIP" has 25 letters. It can be written 2 ways, 13 X 2, with the addition of one "null" letter (X) or as 5 X 5.

Write one letter on one line and the next letter on the line below it. This divides the message into a series columns.

If we wanted to write our code in 13 X 2 it would look like this (13 columns across, two rows down)

A L P F H L P A S N A H P

S I O T E I C N I K S I X

Then move the bottom line after the top line to look like:

ALPFHLPASNAHPSIOTEICNIKSIX

or as 13 "words": **AL PF HL PA SN AH PS IO TE IC NI KS IX**

(The X is there as a "null" letter, or space filler, so the code will fit into the pattern since 13 x 2 = 26)

Our message could also be written in 5 X 5 (5 columns across, 5 rows down):

A O L N A

S F I S S

L T P I H

I H C N I

P E A K P

Reading across each line, rewrite the text as one long line:

AOLNASFISSLTPIHIHCNIPEAKP

or as 5 "words": **AOLNA SFISS LTPIH IHCNI PEAKP**

CODE WORKSHEET #1

Using the Rail-Fence code, transpose these sentences into code.

#1

SOUND IS A MECHANICAL WAVE IN MATTER

(Hint: this can be written in 6 X 5, 15 X 2, or 10 X 3)

#2

PAMPANITO'S HULL IS MADE OF HIGH TENSILE STEEL

(Hint: ignore punctuation)

#3

FOOD ON SUBMARINES WAS GREAT

CODE WORKSHEET #2

Using the Rail-Fence code, decipher the following sentences.

#1 (5 X 8)

PODLA AIWER MSAEI PARTN AWTSE NOWUX IROBX TLFMX

#2 (9 X 6)

PIAEFFAEL ATCMTINNI MOOEECDTS PHMNNESYT AAPTOREEE NDLOFSVND

#3 (2 X 16)

VTIW SWIW TMOA URRI WTEI BMSE IOTR EGAX

#4 (? X ?)

MEFSV EOOOA TYUET TFCYO OBRHT TETPU NSEOH AHORE EBMEN

LESSON: NAVIGATION VOCABULARY

Time: 50 minutes

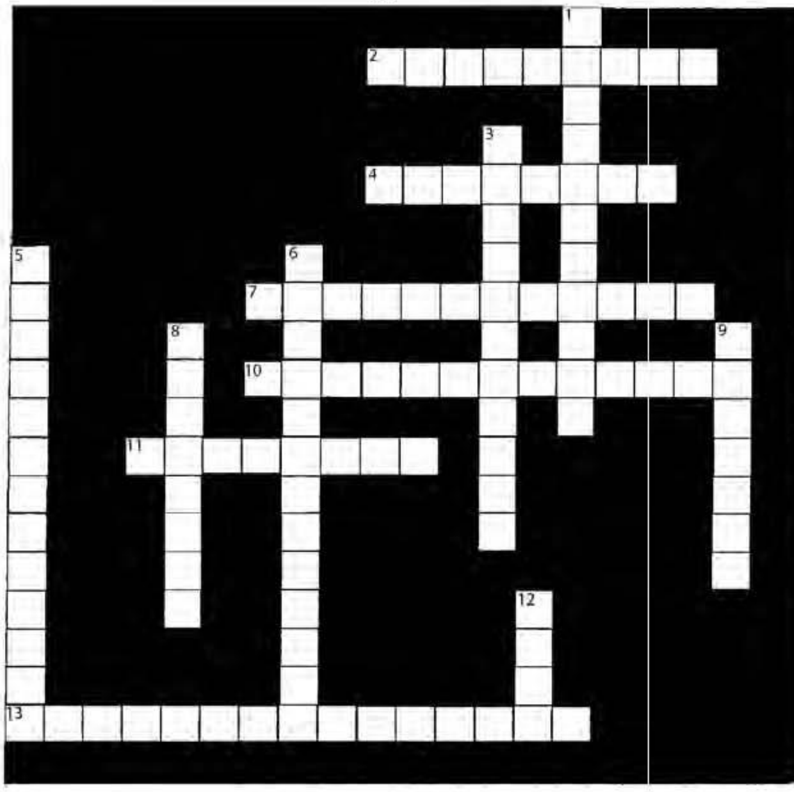
Goal: To gain an understanding of basic navigation vocabulary.

Objective: Students will correctly complete the Navigation Crossword puzzle.

Vocabulary:

- **Absolute Location:** a point on a map or globe expressed as the intersection of lines of latitude and longitude, i.e. San Francisco is at 38º N 122º W
- **Compass Rose:** A compass printed on a nautical chart
- **Dead Reckoning:** A procedure, using course, speed, and drift data or estimates to determine your position. The term is believed to be a corruption of deduced reckoning.
- **Geographic (true) North:** The northern most point on the earth: the North Pole
- **Heading/bearing:** The direction a ship is pointed
- **Knot (speed):** A unit of speed equal to one nautical mile (6,080 feet) per hour
- **Latitude:** Measure of distance in degrees, minutes and seconds, north or south of the equator. Latitude lines run parallel to the equator.
- **Longitude:** Measure of distance in degrees, minutes and seconds east or west of the Prime Meridian at Greenwich. Longitude lines run from geographic north to geographic south.
- **Magnetic North:** The point on earth to which compasses needle points. Nautical Mile: The length of one minute or arc of the great circle of the earth. 6,080 feet
- **Relative Location:** a location expressed in terms of a reference point or area, i.e. San Francisco is north of Los Angeles.
- **Statute Mile**: 5,280 feet
- **Universal Time:** Greenwich Mean Time (GMT), as measured from Greenwich, England. As you move away from Greenwich you will move through different time zones. This is represented by GMT plus 1 (hour) or GMT minus 1 (hour) for each time zone you enter. California is 7 hours "earlier" than GMT, so it would be written as GMT minus 7.

Navigation Crossword



Down

1. a mile measure at 5,280 feet
3. a compass printed on a nautical chart
5. a procedure, using course, speed, and drift data or estimates to determine your position.
6. the direction to which a compass needle points
8. a location expressed in terms of a reference point or area
9. direction a ship is pointed
12. a unit of speed equal to one nautical mile per hour

Across

2. measure of distance in degrees, minutes & seconds, east or west of the Prime Meridian at Greenwich
4. a location or point on a map expressed as the intersection of lines of latitude and longitude
7. the length of one minute of arc on a great circle of the earth (or 6,080 feet)
10. the time at the Prime Meridian in Greenwich, also referred to as Greenwich Mean Time (GMT)
11. measure of the distance in degrees, minutes and seconds north or south of the equator
13. the northernmost point on the earth, the North Pole

LESSON: NAVIGATION

Time: 50 minutes

Goal: To gain an understanding of basic navigation.

Objective: Students will:

- Understand how to use a nautical chart
- Understand universal time
- Understand dead reckoning
- Know basic geography of the Pacific
- Know how to read a compass rose
- Be able to use latitude and longitude to identify positions
- Know how to use navigation tools i.e. parallel
- Be able to calculate Time, Speed and Distance

Materials:

- Navigation chart for class use (among the inserts in this guide)
- Parallel rulers
- Sharp pencil
- Ruler

Background:

Navigation is the art and science of determining where you are, what direction you are traveling, how far you have traveled, and how to get to your final destination.

If you are near the coastline, you will probably measure the directions of prominent landmarks and use triangulation to establish your position. This is called "piloting".

If you are out of sight of land you may use celestial objects such as the sun, moon, planets, and stars. With a sextant you would measure the angle of these objects above the horizon, and from those angles you would derive your position. This is called celestial navigation.

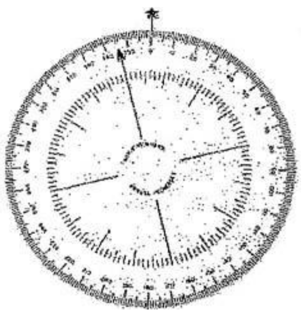
If you are out of sight of land and cannot see any celestial objects (due to clouds or fog) you will have to depend on deduced or "dead" reckoning. Starting from where you knew you were at a specific point in time, you estimate your speed and direction. If you draw this information as a line on your chart, the end of the line is the best guess as to where you are.

The importance of a chart:

A navigator's most valued publication is his chart. A chart is like a road map. A chart gives navigators all the information they will need to know to move through water safely. Without a chart, navigators are almost helpless. A chart will tell a navigator where the vessel is, where the destination is, how far away it is, the safest way to reach it, where to safely wait out a storm, the depth of the water and what the bottom is like (sand, coral, rock, or mud). A chart will also show dangers that are lurking just under the water, like a reef, sunken ship, sudden shallow area, or a rock that is only visible at low tide.

Elements on a chart:

The horizontal and vertical lines on a chart are ***lines of latitude and longitude*** respectively. They provide a grid reference system used for measuring position. When written as coordinates, latitude is expressed first. Latitudes above the equator are designated with an N. Those below the equator are designated with a S. Example: San Francisco is at 38ºN. Sydney, Australia is at 34ºS. Longitude lines are designated as W or E. Example: San Francisco is at 122º W. Sydney, Australia is at 151ºE. The coordinates for San Francisco are 38ºN 122ºW.



The ***compass rose*** is a compass printed on a navigation chart in several locations. The compass rose has two rings. The outer ring is ***True North*** (geographic) and the inner ring is ***Magnetic North***. (The compass rose is placed very carefully on the chart, with Magnetic North ALWAYS pointing exactly north.) A "+" often is present to mark the exact center of the compass rose.

Latitude and longitude lines on a map determine True North. Magnetic North is determined by the earth's magnetic field. When working with a magnetic compass, always use Magnetic North. For this practice we will use True North.

Charts always have a ***key*** to let the user know the scale of the chart. The key will tell you what distance on the chart equals a certain number of miles.

Example:

50 50 100 nautical miles

Equipment needed to use a chart:

Parallel rules are two plastic straightedges that are connected by two moveable metal strips. They can be closed so they are side by side or they can be opened so they are several inches apart. No matter the distance between the rulers, they will always remain parallel to each other, and thus, will indicate the same course.

A **divider** is used for measuring distance. It has two-pointed metal legs that are hinged at the top. The legs can be opened to various spans.

How to plot our location

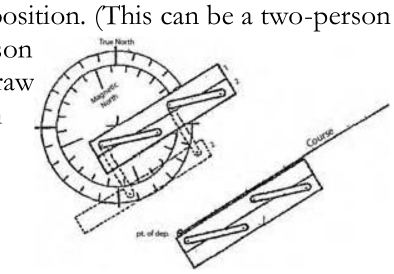
1. Place the navigation chart on a flat surface. It is very important that the chart does not move while we are plotting our location; it should be taped down or held firmly.

2. Locate the starting point: the starting point will be 33º S 151º E, Sydney, Australia

3. Route Instruction: travel on a heading of 49º for a distance of 500 nautical miles at a speed of 20 knots.

To do this, find the compass rose on our chart. Line the parallel up so it crosses **both** the center + the 49º (49 degree) mark, using true north. We now have the parallel at a 49º angle.

4. **Without changing the angle of the parallels**, "walk" the parallels over to our position. (This can be a two-person job. One person should hold the straightedge of the parallel still while the other person moves the second straightedge.) When the parallel is lined up with the submarine, draw a line. (Use a well-sharpened pencil or your position will be off a few degrees at each course change.) This line is called the "line of position." The boat will sail along this line of position for the designated number of miles.



5. To determine the distance on this chart, use the following scale: 1" = 267 nautical miles. Use a ruler to plot the boat's new position along the line of position. If you have dividers, you can use these to mark the position. Where did we end up? We should be at Noumea, New Caledonia.

Now that we know our distance and our speed, use the following formula to find out how long this leg of the patrol took:

$$\text{TIME} = \frac{\text{DISTANCE}}{\text{SPEED}}$$

Example: How long would it take to travel 60 miles at 15 knots an hour?

$$\text{TIME ?} = \frac{60 \text{ nm}}{15 \text{ kts}}$$

60 nautical miles divided by 15 nautical miles per hour (knots) = **4 hours**

For our route from Sydney, we know we have traveled 1200 nautical miles at a speed of 20 knots.

$$\text{TIME ?} = \frac{1200 \text{ nm}}{20 \text{ kts}} = \textbf{60 hours}$$

NAVIGATION WORK SHEET #1

Plotting a course
Use the Pacific Ocean chart that was sent along with this guide to complete this activity. For the purpose of this exercise on the chart, consider 1(of longitude or latitude to equal 60 nautical miles. Also, for this chart 1 inch equals approximately 267 nautical miles. (However, the further north or south of the Equator you travel the use of this number becomes less reliable because of the type of map projection.) A speed of 1 knot means 1 nautical mile per hour. Don't worry if your course crosses land anywhere—we will assume you sailed around any land obstacle. When calculating distances, round off to the nearest mile.

1. On your chart, plot your start point: 22º N 158ºW Where are we?

2. Begin your voyage from this point. Use the compass rose when necessary, with parallel rules.

- From starting point: sail a straight course to 20(N 160(W and mark the spot with a dot—this is location #1
- From location # 1: sail a straight course west for 300 nautical miles and mark the spot.
- From location # 2: sail a straight course to 25(N 170(W. What is the distance between location #2 and the new location in nautical miles?
- From location # 3: proceed on a heading of 0º for 240 nautical miles. What is our new latitude and longitude coordinates?
- From location # 4: proceed to coordinates 28(N 177(W. Where are we and what was our compass heading to get here?
- From location # 5: travel on a heading of 240(until you come to an island—what is it? (Hint: it was the site of a well-known World War II battle.)
- From location # 6: proceed on a heading of 193(for a distance of 1735 nautical miles to an island in the Solomons. Where are we?
- From location #7, proceed on a heading of 200(for 1185 miles to our destination—a major Australian port. Where are we?

3. If you were traveling at a speed of 15 knots to cover the distance between location #1 and location #2, how long did it take you to reach location #2?

4. Traveling at a speed of 20 knots between location #4 and location #5, how long did this leg of the journey take?

5. How long did it take to complete the entire voyage if your speed averaged 15 knots?

PRE-VISIT QUIZ

Buoyancy:

Can 100 pounds of steel float in water? Explain your answer.

Codes:

Decode the following message. YEN IES RGN ODO STS NAT UTW COY ATA NOT OPO VIS EKH DAU IOK

Navigation:

If you travel at 15 knots for 4 ½ hours, how far will you have gone?

How long will this take to travel 30 nautical miles at 6 knots?

If you travel 480 nautical miles in 30 hours, what is your average speed?

Optics:

Where would you position mirrors so you can see the black square? You cannot see through solid lines! Draw the mirror(s) and the path your vision would take.

APPENDIX

TEACHER'S STATION ON BOARD: MAKING A CHEMICAL BATTERY

This is one of the activities students will work on during the program. Please review it carefully, as you, the teacher, will be responsible for supervising this activity. Do not do this activity in the classroom; however, you should review battery principles with your class so students can understand what is happening when they actually make their own batteries during this program activity.

Background: When submerged, *Pampanito* ran on battery power. The chemical battery you will make changes chemical energy into electrical energy.

The battery is made up of two different metals (the aluminum foil and the copper wire). These are called **electrodes**, which are the parts of a battery where electric current enters or leaves the battery. The electrodes are placed in a liquid containing an **electrolyte**, which is a solution that can conduct electricity.

Atoms in the lemon juice take electrons from the atoms that make up the galvanized nail. The lemon juice then transfers them to the atoms that make up the copper foil. The electrons can then flow through a second copper wire connected to the foil.

In this sort of circuit, the zinc nail is the negative terminal and the copper foil is the positive terminal. Electrons travel from the negative terminal through a connecting wire to the positive terminal and then back to the lemon.

Materials (per group):

- 1 - 16" copper wire
- 1 sheet of copper foil
- 1 - 2.47 v. lamp
- 1 extra wire with alligator clips attached to both ends
- 1/4 sheet of paper towel
- safety goggles
- 4 lemons
- propeller motor
- 1 galvanized nail and one copper
- Voltmeter
- 1 - lamp holder (with wire and alligator clips attached)

Procedure:

1. Carefully squeeze the lemon or roll it on the table to loosen the juices inside.

2. Insert the copper nail close to one end of the lemon, leaving enough nail exposed for the alligator clips to grip.

3. Insert the zinc nail close to one end of the lemon, leaving enough nail exposed for the alligator clips to grip.

4. Attach one end of one wire to the zinc nail.

5. Attach one end of the other wire to the copper nail.

6. Place the red multimeter probe (+) on the copper wire and the black probe (-) on the zinc. -Record voltage reading. __________ volts.

7. Disconnect the multimeter and attach the free end of each wire to the light bulb.

8. Disconnect the light bulb and attach the buzzer.

9. Next, see if your battery will light the lamp. Touch one alligator clip to the copper wire and the other clip to the aluminum foil.

10. How long does your light stay lit? _______sec.

11. Disconnect your leads and let your battery "rest" before reconnecting. What are your observations and why do you think this might be happening?

Teacher Tip: The voltage will be extremely weak. You may need at least 3 lemons per battery for any visible movement to occur on the voltometer.

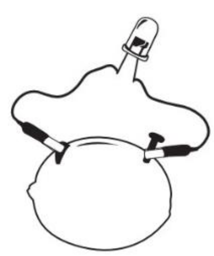
Group Challenge:

1. Using the batteries you've created with your group, build a series circuit.

   a) Predict the total voltage: _________volts

   b) Using the voltmeter, measure the voltage of the batteries in series: ________volts

   c) How does this voltage compare to the voltage produced by just one battery?



2. Draw a diagram of your design.

3. With the members from your group, connect the series circuit to make the propeller motor rotate.

Discussion Questions:

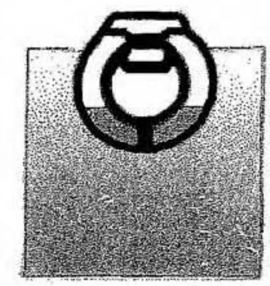
1. How does the voltage of your battery compare to the voltage of the Pampanito's batteries?
2. What did the Pampanito use instead of lemons and nails?
3. What was the purpose of the batteries on the Pampanito?
4. How has battery technology changed since the Pampanito?

BACKGROUND FOR TEACHERS: STATES OF BUOYANCY

By definition, buoyancy is the upward force exerted on a floating, or immersed, body and is independent of the weight of the body. The state of buoyancy refers to the ratio between the weight of the body and the weight of the displaced fluid. In the case of submarines, the displaced fluid is seawater.

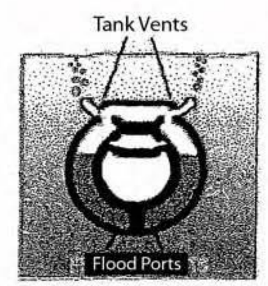
Three states of buoyancy are considered:

- Positive buoyancy
- Neutral buoyancy
- Negative buoyancy.

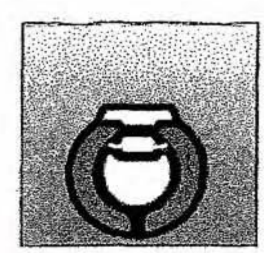


Positive buoyancy exists when the weight of the body is less than the weight of an equal volume of the displaced fluid.

Neutral buoyancy exists when the weight of the body is equal to the weight of an equal volume of the displaced fluid. A body in this state remains suspended, neither rising nor sinking, unless acted upon by an outside force.

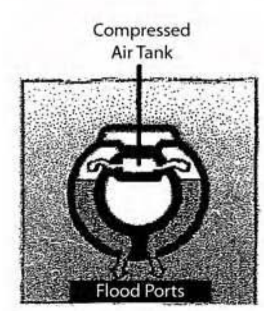


Modern submarines operate on the principle of neutral buoyancy when submerged. In this condition the weight of the submarine is opposed by an equal buoyant force permitting the submarine, theoretically at least, to lie at rest submerged. Not only must weight and buoyant forces be equal, but to keep the submarine on an even keel, they must be in the longitudinal position. This condition must be maintained in seawater of varying density and in different conditions of submarine loading. For the operating submarine, regulating the amount of water in the variable ballast tanks does this. These tanks are for changes in weight and moment necessary to obtain the desired buoyancy conditions. For this purpose they are located at the ends of the submarine (forward and aft trim tanks) and amidships (auxiliary tanks). Water can be transferred from one of these tanks to another, flooded from sea, or pumped overboard.



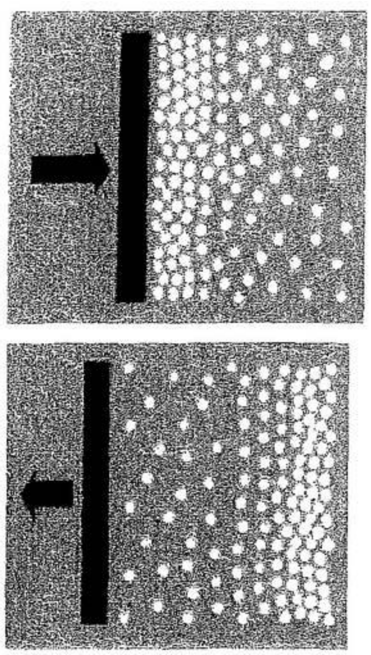
Negative buoyancy exists when the weight of the body is greater than the weight of an equal volume of the displaced fluid and the body sinks.

Theoretically, a submarine is designed with its main ballast tanks of such volume that when they are flooded, the ship is in the state of neutral buoyancy. Negative buoyancy is gained by flooding the negative tank.



BACKGROUND FOR TEACHERS: SOUND IN WATER

Sound can travel through any medium, such as air or steel or water. Submarines are concerned with water as the medium. Imagine an object vibrating back and forth in water. As it moves forward, the molecules of water directly in front of it are pressed closer together. Each molecule then passes this pressure along to the one ahead of it. Thus a state of compression moves away from the object in all directions.



But when the object moves backward, this pressure is removed and the molecules are thinned out. Thus a state of rarefaction follows after each compression.

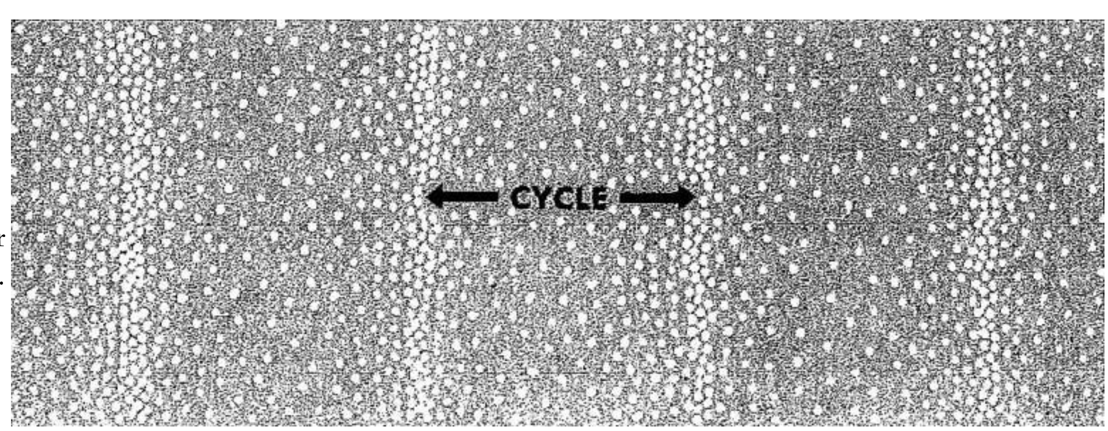
The vibrating object continues to send out compressions and rarefactions one after the other. Each compression - plus -rarefaction is a sound wave.

A single back-and-forth movement of the vibrating object is called a cycle. A single sound wave as shown in this drawing is also called a cycle.

The number of cycles per second is the frequency, and may be expressed in kilocycles (1,000 cycles. For example, a frequency of 16 kilocycles means 16,000 cycles per second.

When sound waves reach our ears through air, the alternating compressions and rarefactions cause our eardrums to move in and out at the same frequency. This vibration is then transferred by tiny bones to the inner ear and then converted to nerve impulses that pass to the brain. Thus the sensation of hearing is produced.

This process includes some additional steps for a submarine sonar operator listening for sounds in water. The sound waves in the water must be picked up by a hydrophone and changed into electric currents. These electric currents are then strengthened and sometimes changed by the use of an amplifier, so that they can be heard through headphones. If the frequency of sound is supersonic (above 15,000 cycles per second or beyond the range of normal human hearing), it must be changed to a sonic frequency (below 15,000 cycles per second) in order to be heard.



Sound traveling in water has its own peculiarities. It travels at a speed of 4,800 feet per second. (It's only 1,100 feet per second in air.) Weak sounds, strong sounds, high frequencies and low frequencies all travel at the same speed. But the temperature, pressure and salinity of the water can affect their speed. These factors can cause sound waves to be bent out of their normal paths. This bending is called refraction. For example, most water is warmer near the surface and cooler at lower depths. Sound waves travel faster in warmer water but are refracted when they hit a patch of cooler water, which alters their speed.

As sound waves move away from their source they grow weaker. There are principally two factors causing this: spreading and attenuation. Spreading is just that, the wave moving from its source spreads out covering a greater area diminishing its strength. Attenuation is the weakening of the sound by other factors, including the friction of water molecules, absorption caused by some underwater objects and scattering caused by others. The effects of attenuation are greater on higher frequencies.

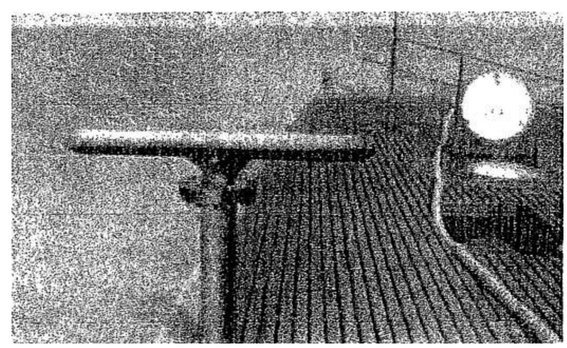
How does this all relate to submarines?

Sounds in water are critical to Navy submarines; both the sounds made by other ships and sounds made by the submarine itself. Sound can give away the location of other ships or your own location. Any ship moving through water makes a certain amount of sound, mostly from the churning of the propellers. Sound also emanates from the various equipment and machinery operating on the ship, as well as the sound of water slapping against the hull. For this reason people are assigned the task of listening for sound on board the submarine.

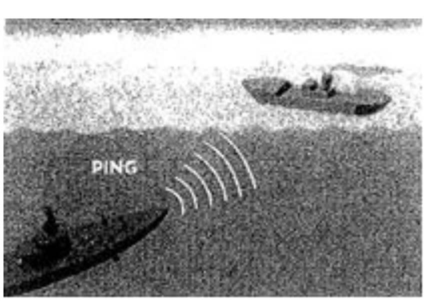
Listening for underwater sounds on a submarine is accomplished through the use of specialized sound equipment, which is generally referred to as **SONAR**. (Like the term RADAR, SONAR is a coined name taken from the first letters of the words SOund Navigation And Ranging.) Listening can be either **passiv**e or **active**.

Passive listening involves using a hydrophone, a type of underwater microphone, to listen for sound. The hydrophone can be turned 360 degrees to permit the listener to sweep the area around the submarine. In this way, detected sounds can be given a bearing so they can know which direction it is coming from.

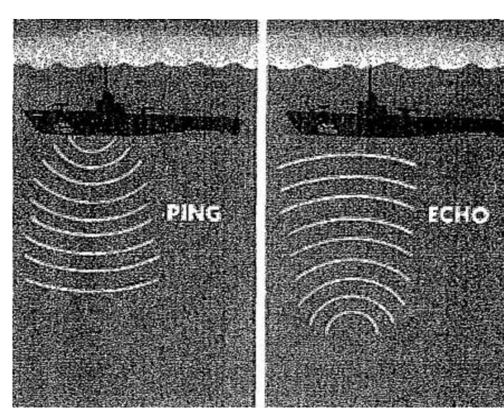
Active sonar involves the sending of a pulse of supersonic sound, called a ping, into the water from a device called a **transducer**. This is also called **echo-ranging**. As its name suggests, echo-ranging permits the user to send a signal with the intent of having it bounce off an object and back to the submarine. The time it takes for the "echo" to return gives a measure of the object's, or possible target's, range. However, besides giving a submarine the bearing of a target, echo-ranging also unavoidably results in giving away the submarine's location to any other ship that may be listening. For this reason, submarines seldom ping, lest the hunter become the hunted.



To determine water depth, submarines also engage in **echo-sounding**. Using a special sound projector, a ping is sent straight down where it will bounce. The returning echo reaches the submarines listening gear, and a depth is shown on an indicator called a **fathometer**. This helps the boat avoid navigation problems in uncharted waters.

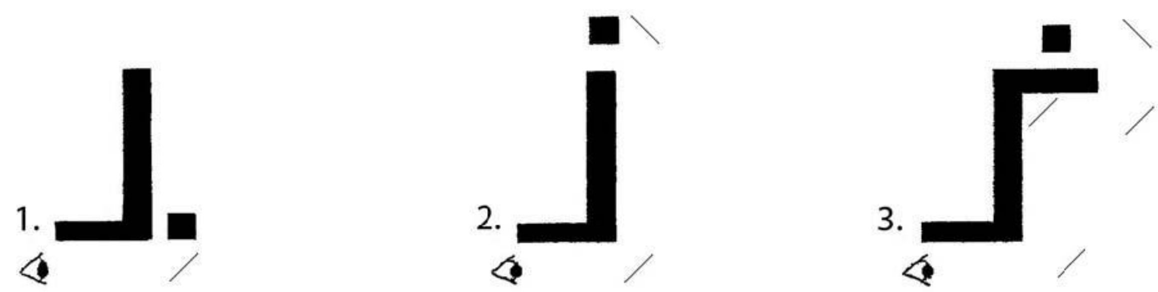


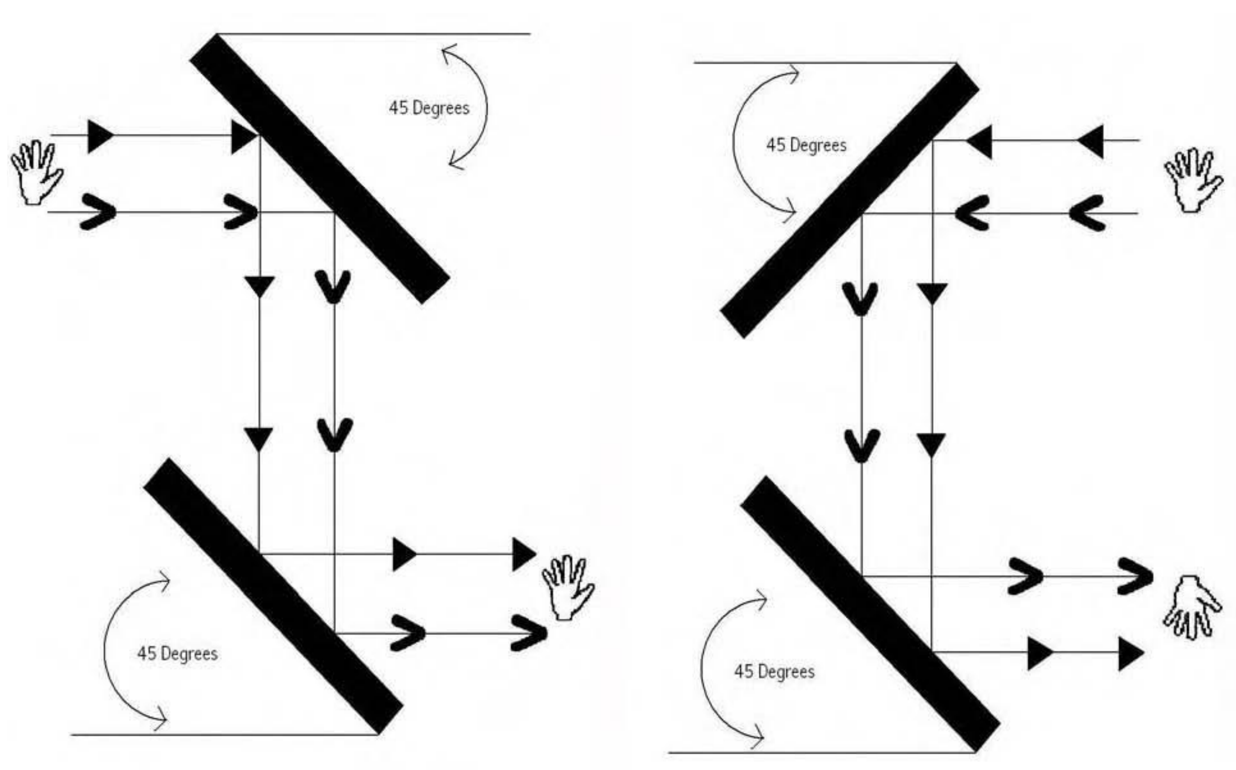
Finally, the effects of refraction of sound waves mentioned earlier could be a great advantage to a submarine evading detection. If a surface ship is echo-ranging in search of a submarine, the submarine can retreat to deeper, cooler waters which may refract the enemy's pings. The enemy ship may simply receive a false echo and never detect the true whereabouts of the submarine. For this reason, submarines are equipped with a special underwater thermometer (bathythermograph) capable of indicating the outside water temperature. This aided in finding a cool place to hide.



LIGHT WORKSHEET ANSWERS

Mirror Positions:





CODE WORKSHEET ANSWERS (#1)

#1 SOUND IS A MECHANICAL WAVE IN WATER (*below are some variations that can be used)*

(6 X 5) SICCVA OSHAET UAALIT NMNWNE DEIAMR

(15 X 2) SU DS MC AI AW VI MT EO NI AE HN CL AE NA TR

(10 X 3) SNSEA CWEMT ODACN AAIAE UIMHI LUNTR

#2 PAMPANITO'S HULL IS MADE OF HIGH TENSILE STEEL

(19 x 2) PA AI OH LI MD OH GT NI ET EA PN TS UL SA EF IH ES LS EL

#3 FOOD ON SUBMARINES WAS GREAT

(4 X 6) FSIS OUNG OBER DMSE OAWA NRAT

CODE WORKSHEET ANSWERS (#2)

#1 PAMPANITO IS A WORLD WAR TWO SUBMARINE

#2 PAMPANITO HAD A COMPLEMENT OF TEN OFFICERS AND SEVENTY ENLISTED

#3 VISIT OUR WEBSITE AT WWW.MARITIME.ORG

#4 **(**Use 9x5) MAY THE TOP OF YOUR SUB NEVER SEE THE BOTTOM OF THE OCEAN

NAVIGATION WORKSHEET ANSWERS

1. The starting point would be ***Honolulu, Hawaii***

2. Here are details for the voyage:

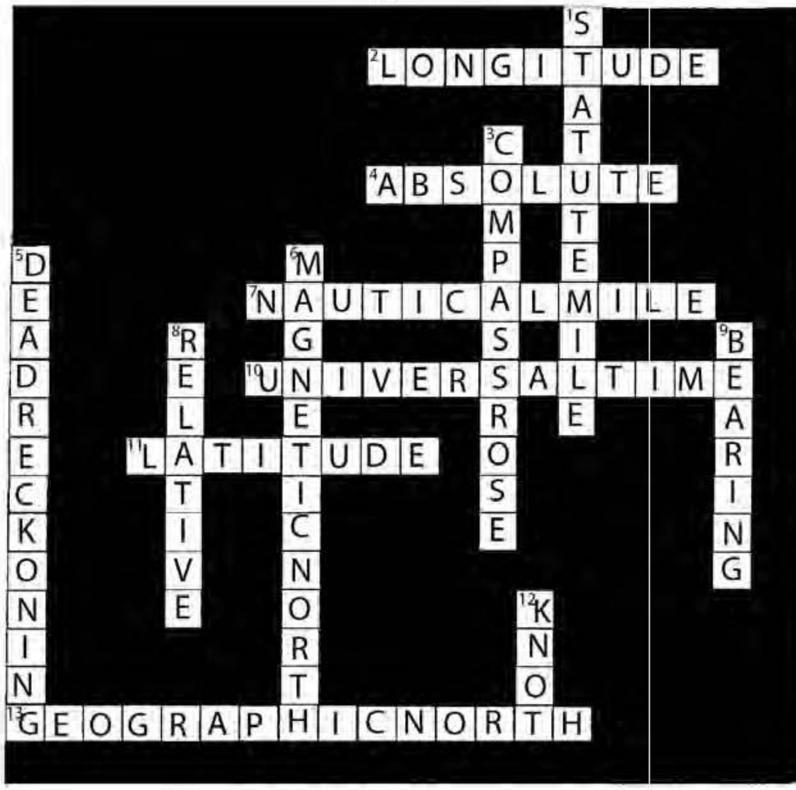
- Location # 1 is a point just southwest of Hawaii—should be easy
- Location #2 is 300 nautical miles directly west, or 5º on the chart, again this should be easy to mark (20ºN 165ºW)
- Location # 3 is a point just above French Frigate Shoal
- Location #4 is easy to find—a 0º heading is directly North and 240 nautical miles is equal to 4º of latitude so you've just moved a little north to 29ºN 170ºW (Note: Here is where distortion enters the picture, at this latitude 1 inch does not equal 267 mile for a north-south measurement like this—it's more like 240 miles)
- Location # 5 is ***Midway Island***—using parallel rules to match your course to the compass rose will reveal a heading of ***262º***
- Location # 6 is on a heading of 240º from Midway—again use parallel rules and the compass rose to get your course and the only island you will run into is ***Wake Island***, famous for the Marines who defended it in WWII
- Location # 7 is a long distance from Wake on a heading of 193º. Remember 1 inch equals 267 miles on our chart, so 1735 nautical miles is 6.5 inches. Set your heading from Wake and measure 6.5 inches until you reach the right place: ***Guadalcanal*** in the Solomon Islands.
- Location # 8 is found the same way: ***Brisbane, Australia***

3. The distance between location #1 and #2 is approximately 300 nautical miles (5º x 60). This distance divided by speed (15 knots) gives a travel time of 20 hours.

4. The distance between location #4 and #5 is 434 nautical miles (1 5/8" x 267 = 434). Distance (434 nm) divided by speed (20 kts) yields a time of 21.7 hours, which converts to ***21 hours and 42 minutes.***

5. To answer this you must tally up the distances between each point. Some of the distances have already been given, so measuring in inches the distance between each point you don't already have a distance for best does this. Multiply by 267 to get the miles in each of the 8 legs of the journey, and then add them up. Our distances were: 150, 300, 434, 240, 434, 1101, 1735 and 1185 for a total of 5579 nautical miles. Distance (5579 nm) divided by speed (15 kts) yields the time: 371.93 hours, which converts to ***371 hours and 56 minutes, or 15 days, 11 hours and 56 minutes.***

Navigation Crossword



Down

1. a mile measure at 5,280 feet

3. a compass printed on a nautical chart

5. a procedure, using course, speed, and drift data or estimates to determine your position.

6. the direction to which a compass needle points

8. a location expressed in terms of a reference point or area

9. direction a ship is pointed

12. a unit of speed equal to one nautical mile per hour

Across

2. measure of distance in degrees, minutes & seconds, east or west of the Prime Meridian at Greenwich

4. a location or point on a map expressed as the intersection of lines of latitude and longitude

7. the length of one minute of arc on a great circle of the earth (or 6,080 feet)

10. the time at the Prime Meridian in Greenwich, also referred to as Greenwich Mean Time (GMT)

11. measure of the distance in degrees, minutes and seconds north or south of the equator

13. the northernmost point on the earth, the North Pole

PRE-VISIT QUIZ ANSWERS:

Buoyancy:

Can 100 pounds of steel float in water? Explain your answer.

Yes, 100 pounds of steel can float if it displaces more than 100 pounds of water. To do this it would need to be spread very thin so it would cover a large amount of surface area.

Codes:

Decode the following message.

YEN IES RGN ODO STS NAT UTW COY ATA NOT OPO VIS EKH DAU IOK

Answer: (Use 9x5)

YOU NEED TO KNOW THIS CODE TO PASS YOUR NAVIGATION TASK

Navigation:

If you travel at 15 knots for 4 ½ hours, how far will you have gone? ***67.5 nautical miles***

How long will this take to travel 30 nautical miles at 6 knots? ***5 hours***

If you travel 480 nautical miles in 30 hours, what is your average speed? ***16 knots***

Optics:

Where would you position mirrors so you can see the black square? You cannot see through solid lines! Draw the mirror/s and the path your vision would take. (/ - denotes mirror position)