TEACHER'S MANUAL

Marine Science

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SECOND EDITION

Waves and Tides

Chapter 4

Introduce the BIG IDEA

Waves and Tides Have students watch a short video clip of ocean waves breaking on the shore. Have them make observations about the movement of water as the wave breaks and then retreats back to the ocean. If any students have been to the ocean, have them share their experience of the water and the waves. Pose students these questions and let them discuss responses in small groups. 1. Why does the size of a wave change as it approaches the shore? 2. What factors affect the tides and make the tide come in and leave again? 3. What hardships do marine organisms deal with that live in the intertidal zones? Small groups can share back with the whole group on key points their groups discussed.

GO ONLINE To access inquiry and investigative activities to accompany this chapter.

Section	Pacing	Main Idea and Key Questions	Ocean Literacy Standards	Labs and Activities
4.1 Introduction to Wave Energy and Motion	1 day	**Waves carry energy across the sea surface but do not transport water.** 1. What are the three most common generating forces of waves? 2. What are the two restoring forces that cause the water surface to return to its undisturbed state?		*Key Questions Activity:* Making Waves
4.2 Types of Waves	2 days	**There are several types of waves, each with its own characteristics and different ways of traveling through the ocean.** 1. What are sources of dissolved substances in seawater? 2. How does salinity affect the density of seawater?	2.d, 5.j, 6.f, 7.e	*Laboratory Manual:* Making Waves (p. 19) *Inquiry Activity: How to Stay Alive in a Tsunami* for "Waves that Kill" *Key Questions Activity:* Natural Hazard PSA
4.3 The Tides	1 day	**Tides result from the gravitational pull of the moon and the sun and from the rotation of the Earth, moon, and sun.** 1. What are tides? 2. What are the three main tidal patterns?	1.c	*Inquiry Activity: Stay in Your Zone!* for "Between the Tides" *Key Questions Activity:* Tide Chart Predictions
Chapter Resources	*Chapter Project:* Coastal Resiliency Planning *Vocabulary Activity:* The Anatomy of a Wave Chapter 4 Test Bank			

4.1 Introduction to Wave Energy and Motion

KEY QUESTION ACTIVITY

Making Waves: In this activity, students will view a demonstration of wave motion (as shown through a slinky), and identify different anatomical structures of a wave.

INTRODUCE

Wind is a generative force that produces small capillary waves and larger, progressive (traveling) waves, depending on the amount of wind energy. It follows that higher wind speeds create larger waves, and more waves are produced if wind continues for a longer period of time. Maximum wind speed, fetch (as seen in large areas of open ocean), and duration form the largest waves. Progressive waves produced by wind can be rolling swells that are evenly spaced. Earthquakes can also produce waves through the action of the seafloor moving and thereby displacing water. Sometimes, large amounts of water are displaced and create tsunamis (seismic sea waves) that can travel long distances and cause coastal damage. The third generating force covered in this chapter also displaces water through landslides or the breaking off of glaciers. These generating forces determine the period of a wave, and therefore the period never changes (only speed can change). Surface tension (working on small ripples) and gravity are the restoring forces that that return water to its undisturbed state.

In all of the waves formed by the generating forces presented in this chapter, waves move in a direction away from the source of the energy, and as energy dissipates, the water particles stop moving their orbital movements. Potential energy comes from the height, or amplitude, of a wave, which is the distance from the crest to the trough.

The movement of the water on Earth is complex due to the interactions (cancellations and reinforcements) of many waves moving at different speeds in different directions on the surface.

TEACH

Saying that waves "travel" can be misleading, as students may think that it is water that is traveling, but instead it is kinetic energy moving forward. As waves pass, water particles only move in a circular orbit and then return to their original position. This can be demonstrated using a floating object in a clear-sided container filled with water.

Differentiated Instruction (Beginner): Parts of a Wave Students should draw a short wave sequence and label the parts of the wave: crest, trough, amplitude, wavelength. Next have them describe the different types of waves that can form and if possible, have them pair up with a partner and practice making the different types of waves. Students could easily use a pan of water, a rope, or even a smart board to produce or draw the different kinds of waves.

Sample Answer: Students should have correctly labelled the parts of the wave with crest being at the top and trough at the bottom of the wave. Amplitude is how tall the wave is from the middle line of the wave and wavelength is the distance from one point on a wave to the same exact point on the next

wave. Types of waves that students will describe are: capillary waves, swells, or tsunamis. Students should point out in their descriptions, the compared amplitudes and causes of the different types of waves.

Connecting to the Big Idea: Have students review Figure 4.5. Ask students to use the diagram to support the claim that waves carry energy and not water. Students should give a real-life observation that also supports this.

Sample Answer: The diagram shows that water is carried up by the energy to make the wave, but as the energy passes, the water cycles back down and remains in the same vicinity. Energy continues to move on making the next wave. Real-life example could be observations of loose particles floating near the surface of water.

ASSESS

Reviewing the Main Idea

1. **Describe** What are the characteristics of each layer of Earth?

   The core consists mostly of iron. The inner core is solid and the outer core is liquid. The temperature of the core is estimated to be over 4000 °C. Most of the mantle is solid, but very hot. The temperature is near the melting point of rocks. Because of this, much of the mantle slowly flows like a liquid, swirling and mixing over hundreds of millions of years. The crust is extremely thin, like a rigid skin floating on top of the mantle.

2. **Compare and contrast** What are the similarities and differences between oceanic crust and continental crust?

   Both are part of Earth's crust and both are less dense than the underlying mantle. Oceanic crust, which makes up the sea floor, consists of basalt that has a dark color. Most continental rocks are of a general type called granite, which has a different chemical composition than basalt and is lighter in color. Oceanic crust is denser than continental crust. Ocean crust is also much thinner than continental crust. Oceanic and continental crusts also differ in age. The oldest oceanic rocks are less than 200 million years old. Continental rocks, on the other hand, can be as much as 3.8 billion years old.

4.2 Types of Waves

INTRODUCE

Deep-water waves, including progressive wind waves discussed above, travel in water that is deeper than one half of their wavelengths, and their speed is dependent on their wavelength. Shallow water waves, alternatively, travel in water that is less than 1/20th of their wavelength. Interestingly, because of their long wavelengths, tsunamis are classified as shallow-water waves. The speed of shallow-water waves depends on the depth of the water, not their wavelength, as interactions with the sea floor cause these waves to slow down. The energy in the wave also picks up sand and sediment on the seafloor, moving it down the beach (since waves refract and do not move perpendicular to the shore). Surf forms when the bottom of a wave slows in this way, but the top of the wave does not

KEY QUESTION ACTIVITY

Natural Hazards PSA: Students will research how tsunamis or rip currents are dangerous to humans, and create a one-minute PSA regarding safety tips.

INQUIRY ACTIVITY

How to Stay Alive During a Tsunami: An Inquiry Activity for Waves that Kill In this activity, students will research the impacts of tsunamis on coastal communities, as well as what coastal communities are doing to keep safe. They will then write a design proposal for a smart phone app that will improve tsunami preparedness among coastal populations.

and spills over. As the wave breaks, the kinetic energy of the wave is transferred to the shore. Intermediate waves display characteristics of booth deep- and shallow-water waves.

Internal waves (a type of progressive wave) occur at boundaries between water of differing densities and aid in ocean mixing, particularly in estuarine environments. Standing waves are not progressive waves because they are enclosed (as in bays) and reflect back on themselves after hitting the geologic boundaries.

TEACH

Differentiated Instruction (Intermediate): The Flow of Water Waves There are two main categories of waves called deep-water and shallow-water waves. They both travel differently through the ocean and have to transition from one to the other. Students should write a short explanation and create a visual diagram of how the two categories of waves transition between each other in the intermediate zone and interact with the sea-floor. Students should include what a riptide current is and create an advisory for beachgoers on what to do if they get caught in a riptide current.

Sample Answer: A deep-water wave is any wave traveling in water that is deeper than one half its wavelength. They are usually generated by the wind and don't interact with the sea-floor until they start to transition to a shallow-water wave. During the transition the deep-water waves begin to feel the sea-floor and refraction begins to occur. The wave portion touching the sea-floor starts to slow down from friction. The top of the wave does not feel the friction so it continues to travel at original wave speed. This causes the wave to become a shallow-water wave with a shorter wavelength. It is steeper and taller until the top of the wave breaks over the slower bottom portion. The diagram should show these behaviors and interactions with the sea-floor. Riptides are areas of rapid seaward-flowing water (water returning to the sea). These are very dangerous areas to swim due to the possibility of a swimmer getting caught in the riptide and swept out to sea. Water-safety courses teach beach-goers to swim parallel to the beach if they find themselves caught in a rip current.

Connecting to the Big Idea: Review longshore transport with students and have them view Figure 4.13. Ask students how various structures on the beach prevent erosion due to longshore transport.

Sample Answer: Energy in a wave picks up and carries sand and sediment along the beach as the wave travels. Barriers help prevent erosion by keeping sand in the same area and breaking up the energy of the wave.

ASSESS

Waves that Kill, Think Critically

1. What causes tsunamis?

Disturbances like earthquakes, landslides, and volcanoes

2. If a warning tells you a tsunami is headed your way, what should you do to increase your chances of survival?

Head to higher ground

3. What are some ways to protect against tsunamis?

Build higher seawalls and protect natural habitats

Reviewing the Main Idea

1. **Describe** How does seafloor spreading occur?

Huge slabs of oceanic crust are separated at the mid-ocean ridges, creating cracks in the crust called rifts. When a rift occurs it releases some of the pressure on the underlying mantle. The reduced pressure allows hot mantle material to melt and rise up through the rift. The ascending magma pushes up the oceanic crust around the rift to form the mid-ocean ridge. When this molten material reaches the earth's surface, it cools and solidifies to form new oceanic crust. The process repeats itself as the sea floor continues to move away from the mid-ocean ridge.

2. **Explain** Why are subduction zones important?

As new lithosphere is created, old lithosphere is destroyed at subduction zones. If this did not occur, the earth would have to expand constantly to make room for the new lithosphere.

3. **Describe** What is the difference between lithogenous sediment and biogenous sediment?

Lithogenous sediment is derived from the physical and chemical breakdown of rocks, mostly on the continents. Fine red clay found on the open ocean floor is an example of lithogenous sediment. Biogenous sediment consists of the skeletons and shells of marine organisms including diatoms, radiolarians, foraminiferans, and coccolithophorids. Biogenous sediment is made mostly of calcium carbonate or silica.

KEY QUESTION ACTIVITY

Tide Chart Predictions: Students will practice reading tide charts to predict coastal water conditions in specific locations at a given time.

4.3 The Tides

INTRODUCE

Location of the Sun, Moon, and Earth in relation to one another, the rotation of Earth on its own axis, underwater bathymetry, the weather, and the shape of the coastline all affect tides, which in turn have a great influence on nearshore life. Because Earth's complete rotation takes one day, and the Moon moves a little in its orbit during that time, two high tides and two low tides are observed over 24 hours and 50 minutes typically. When the two high tides and two low tides are of approximately the same height each day, this is called a semidiurnal pattern. If there is only one high and one low tide each day, due to the seafloor and coast, this is referred to as a diurnal pattern. Spring and neap tides, as well as differing tide levels, occur based on the arrangement of the Sun-Moon-Earth system. Tidal ranges create standing waves in narrow bays and estuaries, while in wide bays or estuaries, no standing waves form due to reduced tidal range. Tides can also (rarely) produce progressive waves that can travel very long distances through estuaries called tidal bores.

Knowledge about tidal levels is important to those who live, work and navigate along the coast, to fishermen, surfers and sailors. Students might enjoy studying

actual tide tables for coastal areas they frequent, if any, or using data to try to create their own tide tables.

INQUIRY ACTIVITY

Stay in Your Zone!: An Inquiry Activity for Between the Tides In this project, students will research the physical factors that define habitat zones in the intertidal. They will then create a poster displaying their findings.

TEACH

Differentiated Instruction (Advanced): Tides Waves & Patterns Tides vary around the world depending on the location of the moon, the effects of the land on the sea-floor, and the shape and location of the continents. Assign students a location in the world such as the Florida Coast in the Gulf of Mexico. Students should identify the types and times of tides the location has using the maps and tables from the chapter reading. This includes the type of main tidal pattern, the tide levels and times, and what water behaviors a beachgoer would notice that would help them identify the tidal pattern. Finally, students should explain the difference between spring tides and neap tides and how each would affect their specific location.

Sample Answer: Florida Coast in the Gulf of Mexico is a mixed semidiurnal tide. This means the area has two high tides and two low tides each day. The low tides occur around 12 am and 12 pm each day and the high tides occur around 6 am and 6 pm each day. During a high tide, the beach would seem to be shrinking because the water level is rising. This is called a flood tide. If the beach seems to be getting bigger, this is during an ebb tide where the water is retracting back to the sea. The Sun produces tidal bulges just as the moon does. A spring tide is a surge of water that causes a rapid high tide because the sun and moon are in line with each other causing their effects on the tides to combine. When the sun and moon are at right angles to each other, their effects on the tides somewhat cancel each other out resulting in a very low tide called a neap tide.

Connecting to the Big Idea: Ask students to explain the difference in semidiurnal tidal patterns between the east coast of the united states and the west coast of the united states. Students should include height of the tides in their description. They may use figure 4.23 as a guide.

Sample Answer: The east coast of North America has semidiurnal patterns which means two low tides and two high tides of the same height during the 24 h day. The west coast has a semidiurnal pattern which means the two low tides and two high tides are of different heights during the 24 h day.

ASSESS

Between the Tides, Think Critically

1. What causes the extreme differences in salinity in the intertidal zone?

   Wave inundation and high tides (high salinity) and rivers and precipitation (low salinity).

2. What are some benefits to living in the intertidal zone?

   High nutrient levels, light levels, food availability, and a good habitat for predator avoidance.

3. What are the four zones of the intertidal environment?

   Splash zone, high intertidal zone, middle intertidal zone, low intertidal zone

Reviewing the Main Idea

1. **Describe** What are the characteristics of the continental shelf, the continental slope, and the continental rise?

   The continental shelf is the shallowest part of the continental margin and is almost flat. The shelf is composed of continental crust and is part of the continent that presently happens to be under water. Continental shelves are, biologically, the richest part of the ocean. The continental slope begins at the shelf break and descends down to the deep-sea floor. The continental slope is the actual edge of a continent and is relatively steep. Submarine canyons beginning on the continental shelf cut across the continental slope to its base at a depth of 3,000 to 5,000 m. These canyons channel sediments from the continental shelf to the deep sea. The continental rise consists of a thick layer of sediment piled up on the sea floor.

2. **Explain** How do hydrothermal vents form?

   At the center of a mid-ocean ridge, the plates are pulling apart. This leaves a gap or depression known as the central rift valley. The floor and sides of the valley are full of crevices and fractures. Seawater seeps down through these cracks until it gets heated to very high temperatures by the hot mantle material. The heated water then forces its way back up through the crust and emerges in hydrothermal vents, or deep-sea hot springs.

3. **Illustrate** Draw a diagram of a mixed semidiurnal tide and label the high high water, low high water, high low water, and low low water points.

   See Figure 4.25 on p. 101 for an example diagram.

VOCABULARY REVIEW

The Anatomy of a Wave
Provide students with the provided drawing of waves on the ocean. Have students label all troughs, crests, and wavelengths they can see. In addition, have them label the amplitude and height of the wave. Make sure they pay attention to detail when labelling, using lines and arrows to note beginning and end of wavelength and amplitude.

Chapter Resources

External Resources

The University of Colorado at Boulder's PhET Interactive Simulations offer students the ability to learn about the physics behind wave motion while varying frequency and amplitude. PhET simulations are free to use and additional teacher resources are available for each simulation. https://phet.colorado.edu/en/simulation/wave-on-a-string

Students can build wave tanks in the classroom using simple materials to explore the behaviors of waves first-hand using the directions supplied by NASA's Johnson Space Center. http://er.jsc.nasa.gov/seh/Ocean_Planet/activities/ts2enac1.pdf

The George E. Brown, Jr. Network for Earthquake Engineering Simulation hub describes how to build a small wave take for teachers who would like to demonstrate wave motion in the classroom on a larger scale. https://nees.org/resources/4459

For advanced classrooms, Oregon State University's Northwest National Marine Renewable Energy Center also provides teachers with detailed instructions and a handbook on how to build and utilize a classroom wave energy device, as well as additional resources. http://nnmrec.oregonstate.edu/education/build-wave-energy-device

The University of Nebraska at Lincoln's Tidal Bulge animation allows students to observe the effects of the moon and sun and the Earth's rotation (users choose which factors to include) on the tides. http://astro.unl.edu/classaction/animations/lunarcycles/tidesim.html

Chapter Project

Coastal Resiliency Planning In this activity, students will research real-world proposals requesting federal funding for coastal communities. Taking what they know about waves and tides, and combining it with their research about coastal resiliency, they will evaluate and critique proposals and make an argument to their peers about which proposals should receive funding.

Chapter 4 Review

Multiple Choice

1. Which area of the ocean has the most favorable conditions for wave formation to occur?

a. between 0° and 10° N

b. between 0° and 10° S

c. between 40° and 50° N

d. between 40° and 50° S

[d]

2. Which is responsible for moving sand down the beach?

a. circular orbit

b. elliptical orbit

c. longshore transport.

d. rip currents

[c]

3. A tide with one low and one high water per day is which type of tidal pattern?

a. diurnal

b. mixed diurnal

c. mixed semidiurnal

d. semidiurnal

[a]

4. Internal waves are important for

a. Longshore transport of sediment

b. Preventing ocean mixing in estuaries

c. Rip currents returning water to the ocean

d. Transporting eggs of organisms that reproduce in the open ocean

[d]

5. What causes water on the side of the Earth opposite the moon to bulge?

a. Refraction

b. Seismic action

c. Centrifugal force

d. Gravitational force

[c]

6. Where are the largest tidal ranges found?

a. Narrow estuaries

b. Large, broad bays

c. Seas with high salinity

d. Polar seas

[a]

7. What factors and features can influence tides along coastlines?

a. Location and sizes of underwater reefs

b. Location and sizes of underwater canyons

c. Shape of the coastline

d. All of the above

[d]

Short Answer

8. Explain how wind speed, fetch, and wind duration influence the formation of waves.?

Higher wind speeds create larger waves. Fetch, or the distance of open water that the wind can blow over without changing distance, also influences wave formation. Areas that have a large fetch will produce more waves than areas with a small fetch. Similarly, the wider the fetch, the more waves that can form. Wind duration is another factor that influences wave formation. More waves are formed when wind continues for a long time.

9. What is the role of centrifugal force in forming tides?

The centrifugal force on Earth arises because Earth and moon both rotate around their combined center of mass, which lies inside the Earth but is offset slightly from the actual center of the Earth because of the presence of the moon. This is called the Earth-moon system. The offset causes the Earth-moon system to wobble slightly, like an unbalanced tire, and creates a centrifugal force that pushes water away from the moon. Thus, on a water-covered Earth the water would form two bulges on opposite sides of the planet, one bulge toward the moon where the moon's gravity predominates and the other bulge away from the moon where centrifugal force predominates. The water would be relatively deep under the bulges and shallow away from the bulges. The bulge of water closer to the moon is larger than the bulge on the opposite side because the pull of gravity is stronger than centrifugal force.

10. Why do tides vary from place to place and time to time?

Three factors that affect tides are continents, islands, and bottom topography. The tides are also influenced by variation in the orbits of Sun and moon relative to the Equator, and the planets have small effects. Even the weather can affect the tides. Strong winds, for example, can pile water up on the shore, causing higher tides than would otherwise occur. In addition to these factors, ocean currents and the Coriolis Effect affects the tides.

11. You observe a beach ball out on the open ocean. Even though the waves appear to move toward you, the beach ball seems to stay out on the ocean, bobbing in place. Explain this phenomenon you are observing.

Students should explain that this is an example of the orbital motion, as opposed to forward displacement, of water particles (and anything floating on the surface of the water) interacting with wave energy. While it looks like water is moving, it is not. Rather, wave energy is traveling from one place to another.

12. Explain why tsunamis are classified as shallow-water waves.

Shallow water waves travel in water that is less than 1/20th of their wavelength. Tsunamis have extremely long wavelengths, so even if the water is deep in the open ocean, it could still be less than 1/20th of the wavelength (which can be 200 km long or more).

Critical Thinking

13. Most tsunamis occur in the Pacific Ocean. How would you explain this?

The Pacific basin is almost entirely circled by boundaries of plates and hence areas of frequent earthquakes.

14. If you owned a seaside home and a bad storm brought heavy winds and high surf to your coastline, would you prefer it to be during a new moon or a quarter moon? Why?

A storm during a quarter moon would be less destructive because tidal range is at its lowest. The highest tides are observed during new and full moons. A storm during these periods would be more destructive since storms cause tides that are higher than predicted tides.

15. Scientific disciplines in reality are not separated neatly into categories as they are in school classrooms. This chapter connected waves and tides to biology, chemistry, physics, astronomy, and anthropology. Discuss patterns you see that are cross-cutting each of these disciplines, citing examples from the text.

Student answers will vary, but for full credit, answers should be supported with answers from the text. Examples from physical science could include, but are not limited to, structure and function of waves, tidal patterns, potential and kinetic energy of waves, and gravitational pull of the sun and moon on tides, as well as Earth's gravity working as a restorative force for wave dissipation. Earth science meets anthropology when discussing human impact, planning for and response to tsunami devastation and/or tidal bores. Biology comes into play with how animals respond to tidal patterns and life in the intertidal zone.

Data Analysis Lab

Claim, Evidence, Reasoning

1. **Claim** How can the accuracy of computer models of tsunamis help both scientists and the public?

The models can help scientists make accurate predictions about tsunami waves very quickly after an earthquake occurs. Scientists can use the models to warn the public about the size of the wave and other factors, such as when and where it will reach shore. With even better warning systems in place, fewer lives may be lost.

2. **Evidence** How do the data predicted by the model compare to the real-time data from the satellite?

Overall, the data predicted by the model are fairly close to the real-time data.

3. **Reasoning** How might the continued comparison of real-time data to computer models help improve the accuracy of future models?

The more comparisons between real-time data and predictions made by computer models, the more opportunities scientists have to refine the models and improve their accuracy.