

1  **CHAPTER 8**

Waves and Water Dynamics

2  **Chapter Objectives**

- Summarize how waves originate.
- Describe wave terminology.
- Understand orbital motion and the difference between deep- and shallow-water waves.
- Cite the relationship between a "sea" and swell.
- Know how wind waves move in what are called "wave trains."

3  **Chapter Objectives (continued)**

- Differentiate between destructive and constructive interference patterns.
- Describe the physical changes in waves as they approach shore and break.
- Recognize differences between wave refraction and wave reflection.
- Discuss the origin, coastal effects, and hazards associated with tsunamis.


4  **Origin of waves**

- Most waves wind-driven
- Moving energy along ocean/air interface
 - Wind main disturbing force
 - Boundary between and within fluids with different densities
 - Air/ocean interface (ocean waves)
 - Air/air interface (atmospheric waves)
 - Water/water interface (internal waves)
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5  **Internal waves**

6  **Other types of waves**

- Splash wave
 - Coastal landslides, calving icebergs
- Seismic sea wave or tsunami
 - Sea floor movement
- Tides
 - Gravitational attraction among Moon, Sun, and Earth
- Wake
 - Ships

7  **Types of ocean waves**

8  **Wave motion**

- Waves transmit energy
- Cyclic motion of particles in ocean
 - Particles may move
 - Up and down
 - Back and forth
 - Around and around
- Particles in ocean waves move in orbital paths

9  **Progressive waves**

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11  **Wave Motion and Refraction**















12  **Orbital waves**

- Wave characteristics
 - Wave steepness = H/L
 - If wave steepness $> 1/7$, wave breaks
 - Wave period (T) = time for one wavelength to pass fixed point
 - Wave frequency = inverse of period or $1/T$

13  **Circular orbital motion**

- Water particles move in circle

- Movement up and down and
 - Back and forth
- 14  **Orbital motion**
- Diameter of orbital motion decreases with depth of water
 - Wave base = $\frac{1}{2} L$
 - Hardly any motion below wave base due to wave activity
- 15  **Deep-water waves**
- Water depth is greater than wave base ($3\frac{1}{2}L$)
 - Wave speed (celerity) proportional to wavelength
- 16  **Shallow-water wave**
- Water depth is $\leq \frac{1}{20} L$
 - Celerity proportional to depth of water
- 17  **Transitional waves**
- Characteristics of both deep and shallow-water waves
 - Celerity depends on both water depth and wavelength
- 18  **Wave development**
- Most ocean waves wind-generated
 - Capillary waves (ripples) formed first
 - Rounded crests, very small wavelengths
 - Increasing energy results in gravity waves
 - Symmetrical waves with longer wavelengths
 - Increasing energy results in trochoidal waveforms
 - Crests pointed, troughs rounded, greater wave heights
 - Sea = area where waves generated by storm
- 19  **Wave development**
- 20 
- 21  **Wave energy**
- Factors that control wave energy
 - Wind speed
 - Wind duration
 - Fetch
- 22  **Maximum wave height**
- Reliable measurement
 - Wave height 34 m or 112 ft
- 23  **Wave energy**
- Fully developed sea
 - Maximum wave height, wavelength for particular fetch, speed, and duration of winds at equilibrium conditions
 - Swell
 - Uniform, symmetrical waves that travel outward from storm area
 - Long crests
 - Transport energy long distances
- 24  **Swell**
- Longer wavelength waves travel faster and outdistance other waves
 - Wave train = group of waves with similar characteristics
 - Sorting of waves by their wavelengths is wave dispersion
 - Wave train speed is $\frac{1}{2}$ speed of individual wave
- 25  **Swell wave train**


- 26  **Wave interference patterns**
- Different swells coming together
 - Constructive interference
 - In-phase wave trains with about the same wavelengths
 - Destructive interference
 - Out-of-phase wave trains with about the same wavelengths
 - Mixed interference
 - Two swells with different wavelengths and different wave heights
- 27  **Wave interference patterns**
- 28  **Waves approach shore**
- Deep-water swell waves shoal
 - Transitional waves
 - Shallow-water waves
 - Wave speed decreases
 - Wavelength decreases
 - Wave height increases
 - Wave steepness increases
 - Waves break
- 29  **Shoaling waves**
- 30  **Breakers in surf zone**
- Top of wave topples over base because of decrease in wave speed due to friction with seafloor
 - Wave form not sustained
 - Different types of breakers associated with different slope of seafloor
- 31  **Spilling breaker**
- Water slides down front slope of wave
 - Gently sloping seafloor
 - Wave energy expended over longer distance
- 32  **Plunging breaker**
- Curling crest
 - Moderately steep seafloor
 - Wave energy expended over shorter distance
 - Best for board surfers
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- 33  **Surging breaker**
- Breakers on shore
 - Steepest seafloor
 - Energy spread over shortest distance
 - Best for body surfing
- 34  **Wave refraction**
- As waves approach shore, they bend so wave crests are nearly parallel to shore
 - Wave speed proportional to depth of water (shallow-water wave)
 - Different segments of wave crest travel at different speeds
- 35  **Wave refraction**
- 36  **Wave energy distribution at shoreline**
- 37  **Wave reflection**
- 38  **Standing waves**
- Two waves with same wavelength moving in opposite directions
 - Water particles move vertically and horizontally
 - Water sloshes back and forth
- 39  **Tsunami or seismic sea wave**

- Sudden changes in seafloor caused by
 - Earthquakes, submarine landslides, volcanic eruptions
- Long wavelengths (> 200 km or 125 m)
- Shallow-water wave
- Speed proportional to water depth so very fast in open ocean
- Sea level can rise up to 40 m (131 ft) when tsunami reaches shore


40  **Tsunami or seismic sea wave**

41  **Tsunami or seismic sea wave**


- Most occur in Pacific Ocean (more earthquakes and volcanic eruptions)
- Damaging to coastal areas
- Loss of human lives
 - Example, Krakatau eruption (1883) in Indonesia created tsunami that killed more than 36,000 people
 - Example, Awa, Japan (1703) tsunami killed 100,000 people


42  **Tsunami watches and warnings**


- Pacific Tsunami Warning Center
- Seismic waves forecast possible tsunami
- Tsunami watch
- Tsunami warning
- Evacuate people from coastal areas and send ships from harbors
- Increasing damage to property as more infrastructure constructed near shore

43  **Waves as a source of producing electricity**

- Lots of energy associated with waves
- Mostly with large storm waves
 - How to protect power plants
 - How to produce power consistently
- Environmental issues
 - Building power plants close to shore
 - Interfering with life and sediment movement
- Offshore power plants?

44  **Wave power plant at Islay, Scotland**

45  **Global coastal wave energy resources**

46  **End of CHAPTER 8**

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