Waves
Waves

- A wave is the transmission of **energy** through a medium...this is true for all types of waves!
- The particles of the medium stay in the same general area (there are no “sound particles”)

![Wave diagram](image)
For Simplicity, we will assume that ocean waves are **Sine Waves** (this isn't actually true!)
a. Deep-water wave
Wave Period: *Time* between two waves (T)
Wave Frequency: *number* of waves per unit time (f)
Wave Length: *Distance* between two waves (L)
Wave Speed: Distance/Time, = L/T (C)
Wave Height: Distance between trough and crest (H)
Wave Steepness: Height/Length, H/L
Wave period (seconds)

- 24 hours: Tides
- 12 hours: Long period waves
- 1 hour: Long period waves
- 30 seconds: Infra-gravity waves
- 1 second: Gravity waves
- 0.1 second: Ultra-gravity waves
- 10^-1 second: Capillary waves

Wave energy

Wave frequency (cycles per second)

- $10^{-6}$
- $10^{-5}$
- $10^{-4}$
- $10^{-3}$
- $10^{-2}$
- $10^{-1}$
- $10^0$
- $10^1$
- $10^2$
<table>
<thead>
<tr>
<th>Disturbing force</th>
<th>Restoring force</th>
<th>Type of wave</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>Surface tension</td>
<td>Capillary waves</td>
</tr>
<tr>
<td></td>
<td>Gravity</td>
<td>Wind waves</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Seiches</td>
</tr>
<tr>
<td>Seismic activity, landslides</td>
<td>Gravity</td>
<td>Tsunami</td>
</tr>
<tr>
<td>Gravity</td>
<td>Gravity</td>
<td>Tides</td>
</tr>
</tbody>
</table>
Function

Phase speed, $C$

Deep-water

Intermediate-water

Shallow-water

Limits of application

Deep-water

Intermediate-water

Shallow-water

\[
\left[ \frac{g}{h} \tanh kh \right]^{\frac{1}{2}}
\]

\[
\left[ gh \right]^{\frac{1}{2}}
\]

\[
\left[ \frac{h}{L} > \frac{1}{2} \right]
\]

\[
\left[ \frac{1}{20} > \frac{h}{\Lambda} \right]
\]
Deep water waves NEVER feel the bottom!
b. Intermediate-water wave

Back and forth motion near bottom

C. Shallow-water wave
Wave speeds depend on...

• Deep-water waves: wavelength
  – Longer wavelength, travel faster

• Shallow-water waves: water depth
  – Deeper water, travel faster
Wind-Wave Formation

Waves increase energy by:

1) Wind Speed
2) Duration
3) Fetch
More Definitions...

- **Sea:** local waves formed by wind events
- **Confused Sea:** local irregular waves of many periods and from many directions
- **Fully developed Sea:** the waves that form when fetch, wind speed, and duration are maximal
- **Wave Train:** waves that have left the windy region and are sorted by period
Deep-water waves: longer wavelength, travel faster! So the fast waves move away from the slow waves....
Deep water waves **disperse**
Remember: increase L, increase speed
Result: A long way from storm, ocean waves have one dominant frequency.
(very periodic, rhythmic)

We call this swell.
Waves will keep moving in the same direction until they run into something, or gravity “kills” them…

Constructive

Destructive

Mixed
If we mix many waves of different lengths, from different directions, we get a big mess (a confused sea)
If they all line up, we get BIG waves.... Sometimes called Rogue Waves
Rogue Waves

- Can exceed 100 ft
- “ship-killers”

<table>
<thead>
<tr>
<th>Wind Speed km/h (mil/h)</th>
<th>Average Height M (ft)</th>
<th>Average Length m (ft)</th>
<th>Average Period s</th>
<th>Highest 10% Waves m (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 (12)</td>
<td>0.33 (1)</td>
<td>10.6 (34.3)</td>
<td>3.2</td>
<td>0.75 (2.5)</td>
</tr>
<tr>
<td>30 (19)</td>
<td>0.88 (2.9)</td>
<td>22.2 (72.8)</td>
<td>4.6</td>
<td>2.1 (6.9)</td>
</tr>
<tr>
<td>40 (25)</td>
<td>1.8 (5.9)</td>
<td>39.7 (130.2)</td>
<td>6.2</td>
<td>3.9 (12.8)</td>
</tr>
<tr>
<td>50 (31)</td>
<td>3.2 (10.5)</td>
<td>61.8 (202.7)</td>
<td>7.7</td>
<td>6.8 (22.3)</td>
</tr>
<tr>
<td>60 (37)</td>
<td>5.1 (16.7)</td>
<td>89.2 (292.6)</td>
<td>9.1</td>
<td>10.5 (34.4)</td>
</tr>
<tr>
<td>70 (43)</td>
<td>7.4 (24.3)</td>
<td>121.4 (390.2)</td>
<td>10.8</td>
<td>15.3 (50.2)</td>
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<tr>
<td>80 (50)</td>
<td>10.3 (33.8)</td>
<td>158.6 (520.2)</td>
<td>12.4</td>
<td>21.4 (70.2)</td>
</tr>
<tr>
<td>90 (56)</td>
<td>13.9 (45.6)</td>
<td>201.6 (661.2)</td>
<td>13.9</td>
<td>28.4 (93.2)</td>
</tr>
</tbody>
</table>

North

Agulhas current flow

Still water level

Antarctic storm wave movement

South

Rogue wave