



## Waves

- What are Waves
- Wave Motion
- Wave Energy
- Description of Wavefield
- Waves Approaching Shore
- Coastal Waves



## What is a Wave?

- Transfers a disturbance from one point of a material to another
- No net overall motion to the material >> Energy is transported through the water without any transport of the water itself
- Constant speed and period. But in the ocean since waves interact with the bottom, their speed does change.



## Wave Characteristics

### In Space:

- Amplitude (a)
- Height (H)
- Wavelength (L)
- Wavenumber (k)
- Steepness (H/L)

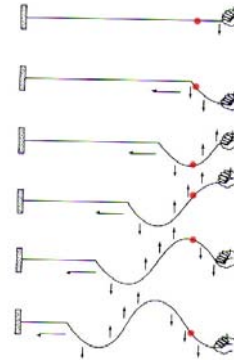
### In Time:

- Period (T)
- Frequency ( $\omega$ )

$$\text{Speed (c)} = L / T$$

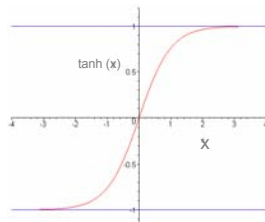


- 2 separate motions:
- Motion of the wave
- Motion of the material



$$c^2 = \frac{g \tanh(kd)}{k}$$

- $kd \ll 1$  or  $d/L \ll 1$  or  $d \ll L$
- $L > 20 d$
- $c^2 = \frac{g}{k} kd$
- $c^2 = gd$
- $c = \sqrt{gd}$
- Shallow Water Waves

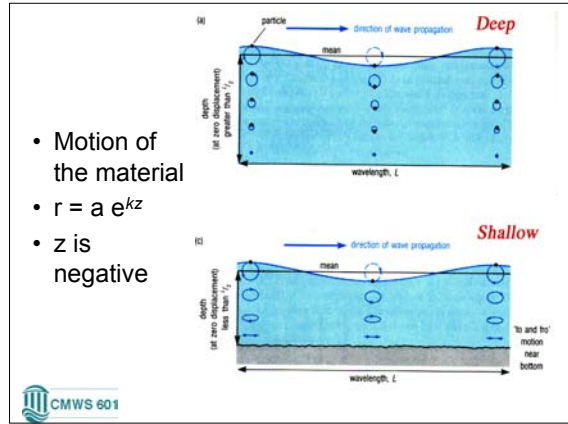
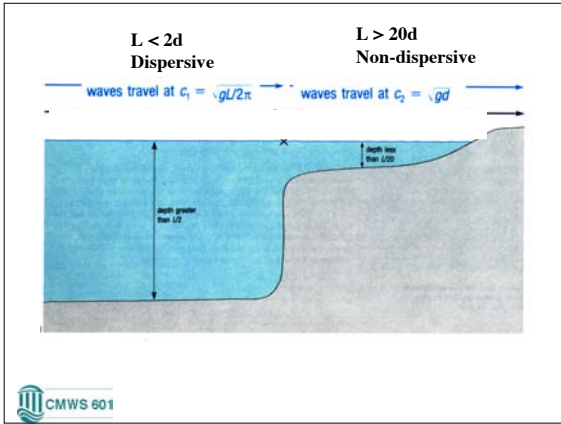


$$c^2 = \frac{g \tanh(kd)}{k}$$

- $kd \gg 1$  or  $d/L \gg 1$  or  $d \gg L$
- $L < 2 d$
- $c^2 = \frac{g}{k}$
- $c^2 = \frac{gL}{2\pi}$
- $c = \frac{\sqrt{gL}}{2\pi}$

Deep Water Waves





### Wave Energy

- Energy =  $\frac{1}{8} \rho g H^2$   
(per unit area)
- Energy Flux = Amount of Energy x Speed of Energy
- What is the energy flux for a shallow water wave?

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### Wave Interaction

- Waves often travel in groups or packets
- Individual waves move with a certain phase speed (c)
- Groups move with a group velocity ( $c_g$ )

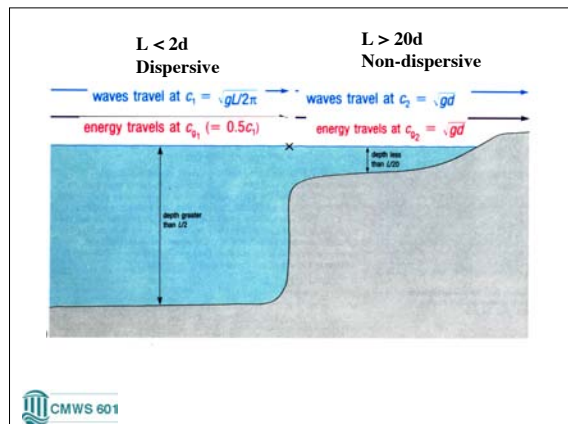
- Animation

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### Wave Interaction: Groups

- Shallow water waves:
  - $C_g = c$
- Deep Water waves:
  - $C_g = \frac{1}{2} \left( \frac{c_1 + c_2}{2} \right)$

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## Making Waves

Energy In >> Wind

1. Capillary Waves ( $L < 1.7\text{cm}$ )
2. Gravity Waves ( $L > 1.7\text{cm}$ )
3. Waves grow in size

dependent on

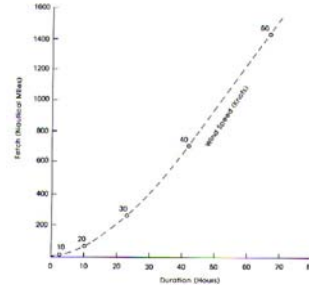
- a) Wind Speed
- b) Duration
- c) Fetch



4. If fetch & duration large enough, equilibrium is reached where Energy In = Energy Out. The waves are at the maximum height for that wind speed and we have a Fully Developed Sea



## Fully Developed Sea



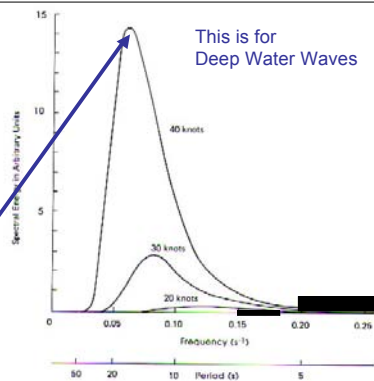
$$H = .031 \times W^2$$

H (m)

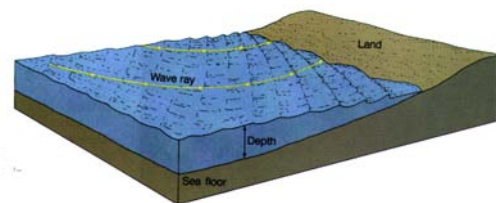
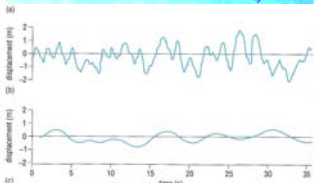
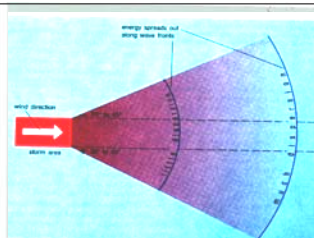
W (m/s)

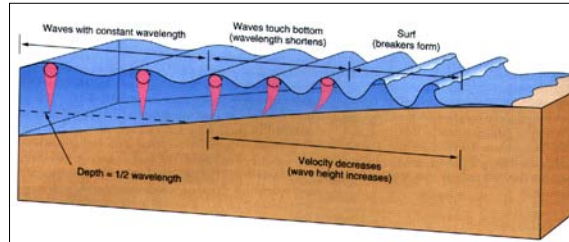
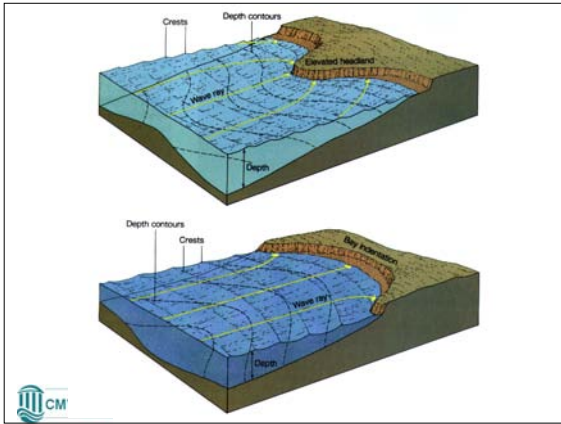


- Shows the Dominant Wave period ( $T_d$ )

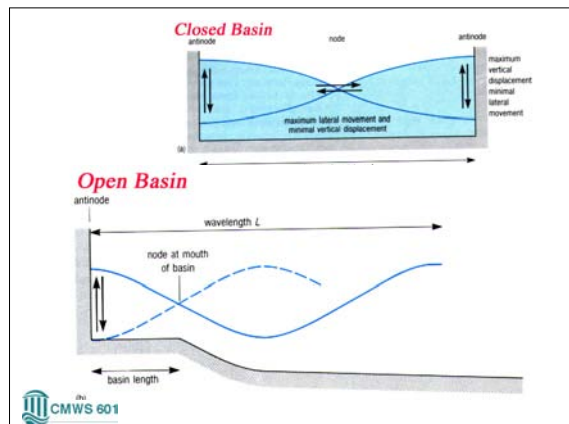
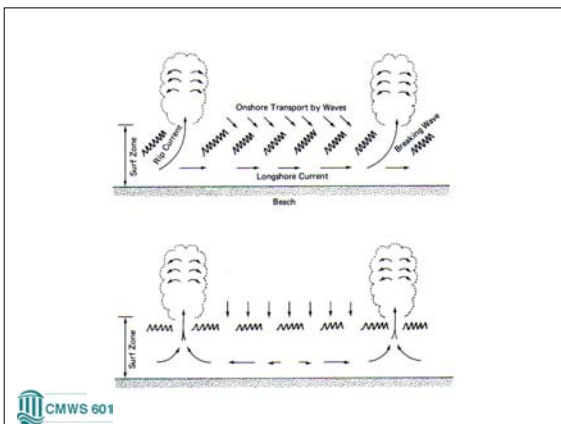
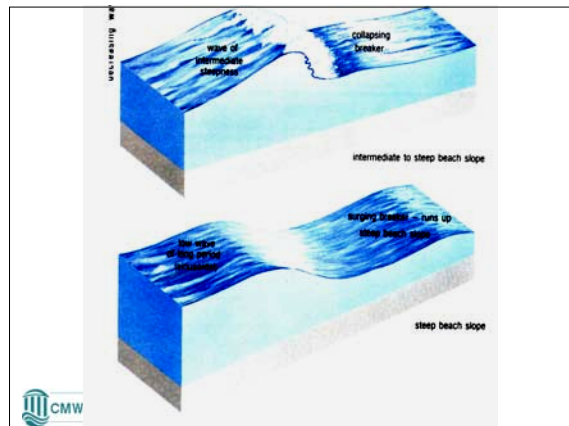
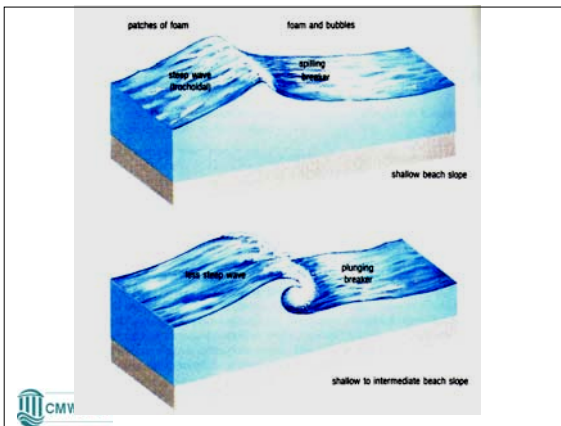


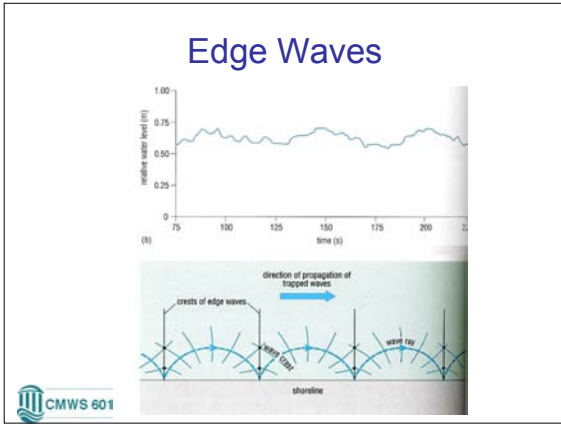
- Ocean surface consists of complex Wavefield described by Significant Wave Height  $H_{1/3}$  = average height of highest 1/3 of the waves
- Waves leave generation site, disperse, travel far from origin as Swell.
- Swell has diminished wave height due to
  - Attenuation
  - Spreading Loss





- Depth decreases
- Speed decreases
- Wavelength decreases
- Energy confined to less area, Height increases





- Edge waves are low-frequency waves attached to the beach.
- $T$  = few minutes, long-shore  $L$  = around a kilometer,  $a$  - decays exponentially offshore

A 3D perspective diagram of edge waves. It shows a cross-section of the ocean and beach. A coordinate system is shown with  $x$  pointing along the shore,  $y$  pointing north, and  $z$  pointing vertically. The diagram illustrates how wave energy is trapped along the shoreline and decays exponentially as it moves away from the beach.

### Tsunami Formation

The diagram illustrates the formation of a tsunami. It shows a cross-section of the ocean and seafloor. A vertical arrow labeled 'Tsunami source' indicates a displacement of the seafloor. This displacement creates a wave that travels through deep water and then into shallow water near the shore. Labels include 'Displacement', 'Seafloor', 'Tsunami source', 'Deep water', and 'Shallow water'.

- In open ocean:
- $L = 100$ 's of km
- $C = (gd)^{1/2} = (10\text{m/s}^2 \cdot 4000\text{m})^{1/2} = 200\text{m/s}$
- $H \sim 1\text{ m}$

### Tsunamis Reaching Shore

- Energy flux is conserved
- Speed of the energy • Amount of energy
- $(gd)^{1/2} \cdot 1/8 \rho g H^2$  is constant.
- When  $d$  quickly decreases,  $H$  quickly increases

### Waves & Coasts

- Input of energy via waves is one of the main driving forces of coastal physical processes
- Grand Strand beaches are wave dominated beaches

Ability of waves to erode a coast depends on:

- 1) Wave Environment
  - Fetch direction
  - Significant Wave Height
  - Frequency of Storms
  - Types of Storms

A satellite image showing a coastal area with a prominent wave pattern, likely a cyclone or storm system, over the ocean.

Depends on

- 2) Geology
  - Rock/sand/sediment type
  - Geological structure
- 3) Coastline Morphology
  - Configuration
  - Topography
  - Bathymetry/Slopes

A photograph showing waves crashing against a rocky coastline, illustrating the effects of geology and coastline morphology on wave energy.