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Introduction to Coastal and Harbor Engineering

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Coastal and Harbor Engineering

- The origin of *Harbor Engineering* dates back to several thousand years.
- A new field of engineering named as *Coastal Engineering* evolved during the second World War.

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Applications of Coastal Engineering Design

- Ports, harbors, breakwaters, seawalls, revetments
- Navigation channels
- Coastal intakes and out-falls
- Ocean pipelines, cables, piles
- Sediment control: groins, sand bypassing, dredging, beach nourishment
- Power generation by waves and tides
- Coastal disasters; tsunami, storm surge

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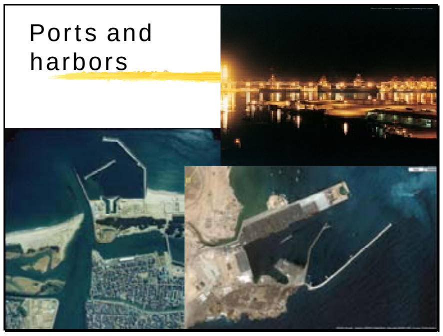

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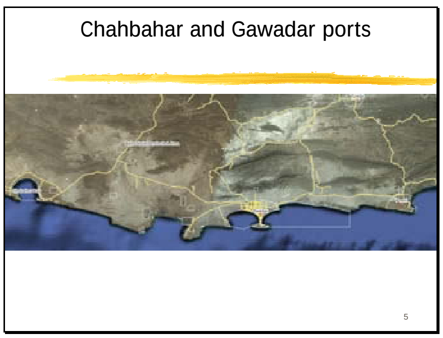

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Burj-ul-Arab, Dubai

(http://stategis.blogspot.com/2006/06/satellite-images-of-dubai-palm-island.html)

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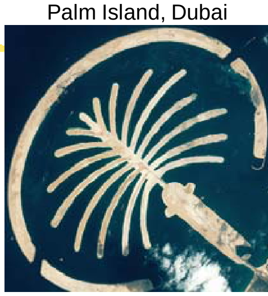
Palm Island, Dubai



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Beach fill, Delaware, U.S.

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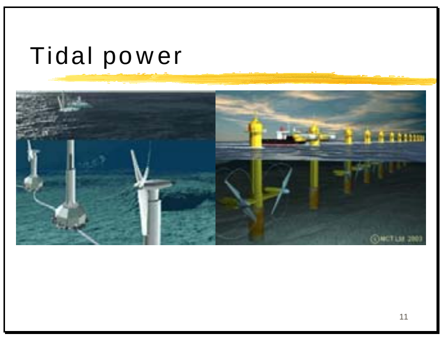

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Methods of Analysis

- Hydrodynamics: Wave theories
- Empirical formulae based on experimental results
- Physical Modeling
- Numerical Modeling

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Wave Theories

- Small amplitude wave theory (airy wave theory or linear wave theory)
- Finite amplitude wave theories
  - Stokes wave theory
  - Cnoidal wave theory
  - Solitary wave theory

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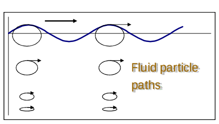
What is a Wave?

- A process by which the energy is transported through a medium



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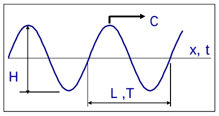
Basic parameters of a wave



H: wave height, L: wave length

T: wave period, C=L/T: wave celerity

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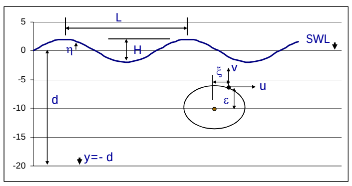
Small amplitude wave theory



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Governing Equations

$$\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} = 0$$ Laplace equation

$$u = \frac{\partial \phi}{\partial x}$$

$$v = \frac{\partial \phi}{\partial y}$$

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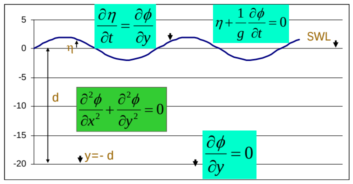
Boundary Conditions



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Functional Relationships

$$\eta = \frac{H}{2}\cos(kx - \sigma t)$$

$$\phi = \frac{H}{2}\frac{g}{\sigma}\frac{\cosh k(d+y)}{\cosh kd}\sin(kx - \sigma t)$$

$$u = \frac{\pi H}{T}\frac{\cosh k(d+y)}{\sinh kd}\cos(kx - \sigma t)$$

$$v = \frac{\pi H}{T}\frac{\sinh k(d+y)}{\sinh kd}\sin(kx - \sigma t)$$

$$p = -\rho g y + \frac{\rho g H}{2}\frac{\cosh k(d+y)}{\cosh kd}\cos(kx - \sigma t)$$

$$k = \frac{2\pi}{L}$$

$$\sigma = \frac{2\pi}{T}$$

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Functional Relationships (continued)

$$\sigma^2 = gk \tanh kd$$

$$L = \frac{gT^2}{2\pi}\tanh kd$$

$$E = \frac{\rho g H^2 L}{8}$$

$$P = \frac{nE}{T}$$

$$n = \frac{1}{2}\left(1 + \frac{2kd}{\sinh 2kd}\right)$$

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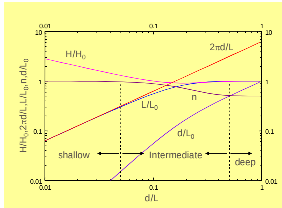
Wave Classification

by Relative depth (d/L)



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Deep and Shallow Water Waves

- Functional relationships are simplified due to the limiting values of hyperbolic functions.
- Particle paths are changed and consequently sediment transport characteristics are different under shallow and deep water conditions.

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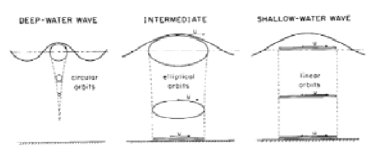
Particle paths in different conditions



A diagram of the orbital motions of Airy waves in deep water where the orbits are circular, and in intermediate water depths where the orbits are elliptical but become flatter and smaller as the bottom is approached. In shallow water Airy theory predicts that all water motions consist of to-and-fro horizontal movements, uniform with depth.

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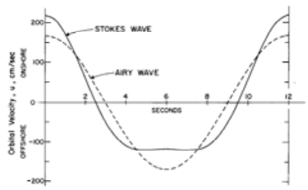
Finite amplitude wave theories



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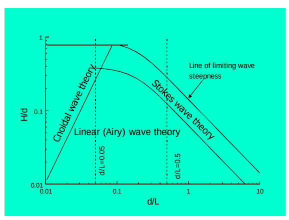
Range of applicability
of wave theories



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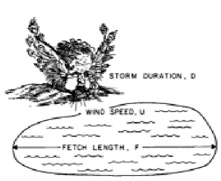
Generation of wind waves



Principal storm factors for wave generation

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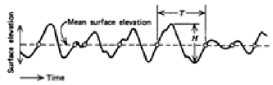
Analysis of a wave record

Zero-up crossing method:



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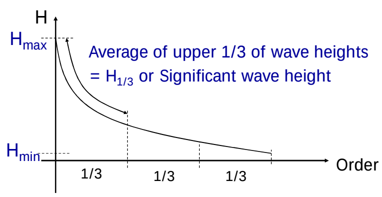
Significant wave height & significant wave period



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A brief introduction to ACES

- ACES: Automated Coastal Engineering System
- Operating System: DOS
- Freeware, unlimited distribution
- Comprehensive documentation
- Easy to use
- Economical by virtue of disk space and RAM
- Covers many coastal engineering applications of practical relevance

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Current ACES Applications	
Functional Area	**Application Name**
Wave Prediction	Windspeed Adjustment and Wave Growth
	Beta-Rayleigh Distribution
	Extremal Significant Wave Height Analysis
	Constituent Tide Record
Wave Theory	Linear Wave Theory
	Cnoidal Wave Theory
	Fourier Series Wave Theory
Wave Transformation	Linear Wave Theory with Snell's Law
	Irregular Wave Transformation (Goda's method)
	Combined Diffraction and Reflection by a Vertical Wedge
Structural Design	Breakwater Design Using Hudson and Related Equations
	Toe Protection Design
	Nonbreaking Wave Forces on Vertical Walls
	Rubble-Mound Revetment Design
Wave Runup, Transmission, and Overtopping	Irregular Wave Runup on Beaches
	Wave Runup and Overtopping on Impermeable Structures
	Wave Transmission on Impermeable Structures
	Wave Transmission Through Permeable Structures
Littoral Processes	Longshore Sediment Transport
	Numerical Simulation of Time-Dependent Beach and Dune Erosion
	Calculation of Composite Grain-Size Distribution
	Beach Nourishment Overfill Ratio and Volume
Inlet Processes	A Spatially Integrated Numerical Model for Inlet Hydraulics

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Example

A wave tank is 193m long, 4.57m wide and 6.1m deep. The tank is filled to a depth of 5m with fresh water and a 1-m high, 4-sec period wave is generated. (a) Calculate the wave celerity and length using small amplitude wave theory. (b) Calculate the corresponding deep water wave length and celerity.

Given:

$d = 5\,m$ $\quad T = 4\,\sec$ $\quad H = 1m$

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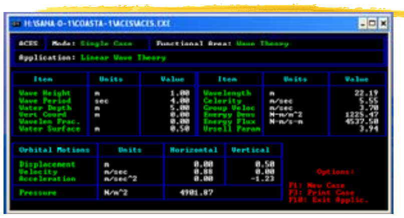
Solution:



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