OCN660 - Ocean Waves

Course Purpose & Outline

Instructor:

Doug Luther

dluther@hawaii.edu

x65875

Kéréon Lighthouse, France; photo: Jean Guichard

This introductory course has two objectives:

- to survey the principal types of linear ocean waves; and,
- to review some mathematical methods used to study all waves.

When combined with a suitable introductory course on fluid mechanics (such as Marine Hydrodynamics, OCN662), this course will provide the student with sufficient knowledge to readily access the detailed derivations and descriptions of oceanic waves found in such upper level books as Kinsman's *Wind Waves*, Phillips' *Dynamics of the Upper Ocean*, LeBlond and Mysak's *Waves in the Ocean*, and Gill's *Atmosphere-Ocean Dynamics*.

Of the five principal oceanic wave types (acoustic, capillary, gravity, inertial or gyroscopic, and Rossby or vorticity) only the latter three will be explored at any length. There is no single book that provides an adequate text for this course, but LeBlond and Mysak's *Waves in the Ocean* and Gill's *Atmosphere-Ocean Dynamics* are recommended references.

The syllabus for this course is provided below. When appropriate, the course is punctuated with modern videos of waves, such as tsunamis, tidal bores, "rogue" waves, etc.

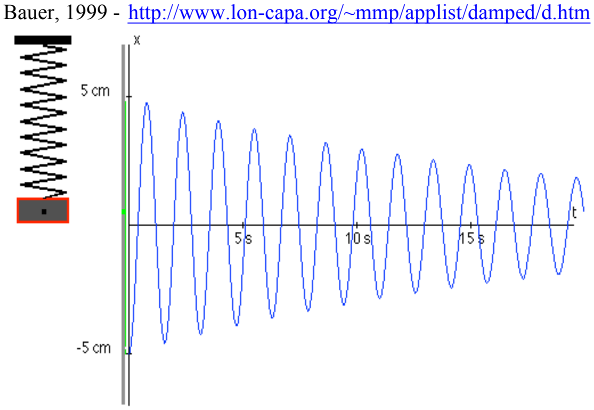
Student Learning Outcomes and prerequisites are listed after the syllabus.

OCN660 - Syllabus

I. Simple Harmonic Oscillator

A. free mode of vibration; natural frequency
  B. forced motion & transients; linear superposition; energy conservation
  C. resonance; **damped oscillations (see →)**
  D. Green's function of the oscillator
    1. impulsive forcing & linear superposition
    2. jump conditions

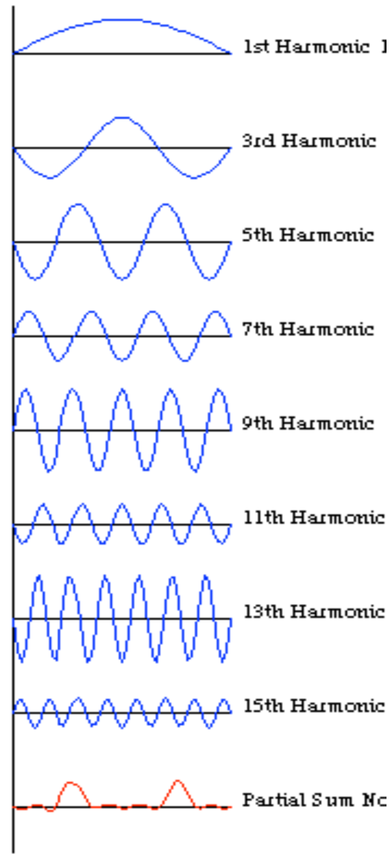
W. Bauer, 1999 - http://www.lon-capa.org/~mmp/applist/damped/d.htm



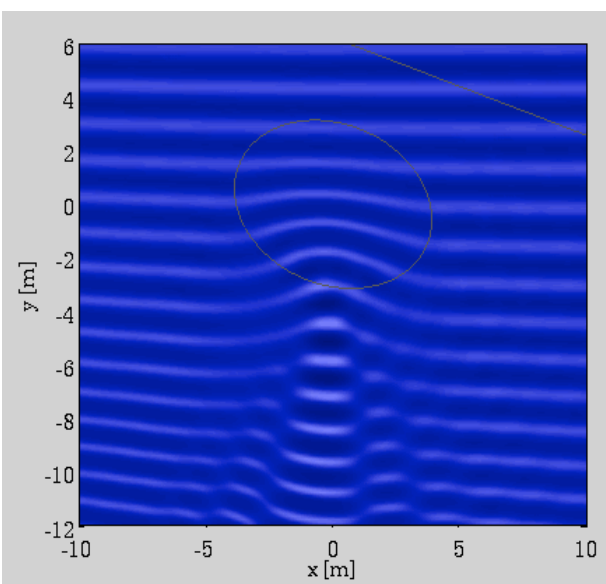
II. The Vibrating String and the Wave Equation

A. infinite string
1. wave (phase) velocity
2. conservation of energy; work due to forcing
3. Green's function; initial value problem; d'Alembert's solution

B. clamped string
1. method of images & reflections
2. eigenfrequencies & **eigenmodes (see →)**; Sturm-Liouville problem
3. solution in terms of d'Alembert's solution
4. distributed forcing; eigenmode solution for homogeneous case
5. projection onto eigenmodes; analogy to Green's function



G. Epstein - http://www.calpoly.edu/~gepstein/NormalModes/index.html



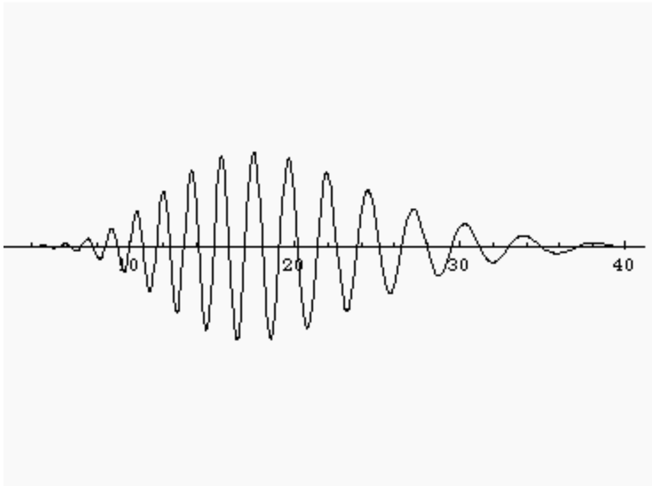
Wave refraction by a symmetric seamount.
Wikipedia: Boussinesq Approximation (water waves)

III. 2-D Wave Eqn. - Non-Dispersive Gravity Waves

A. classification of generic oceanic wave types

B. derivation of 2-D wave eqn. for surface gravity waves
1. no rotation; linearization; acoustic & gravity limits
2. `long-wave' or `shallow-water' approximation
3. diffraction; **refraction** (**Figure** to left)

C. solutions
1. plane waves without boundaries; wavelength & wavenumber
2. boundaries; separation of variables; eigenmodes & frequencies



D. Russell - http://www.acs.psu.edu/drussell/Demos/Dispersion/dispersion.html

IV. 2-D Dispersive Gravity Waves

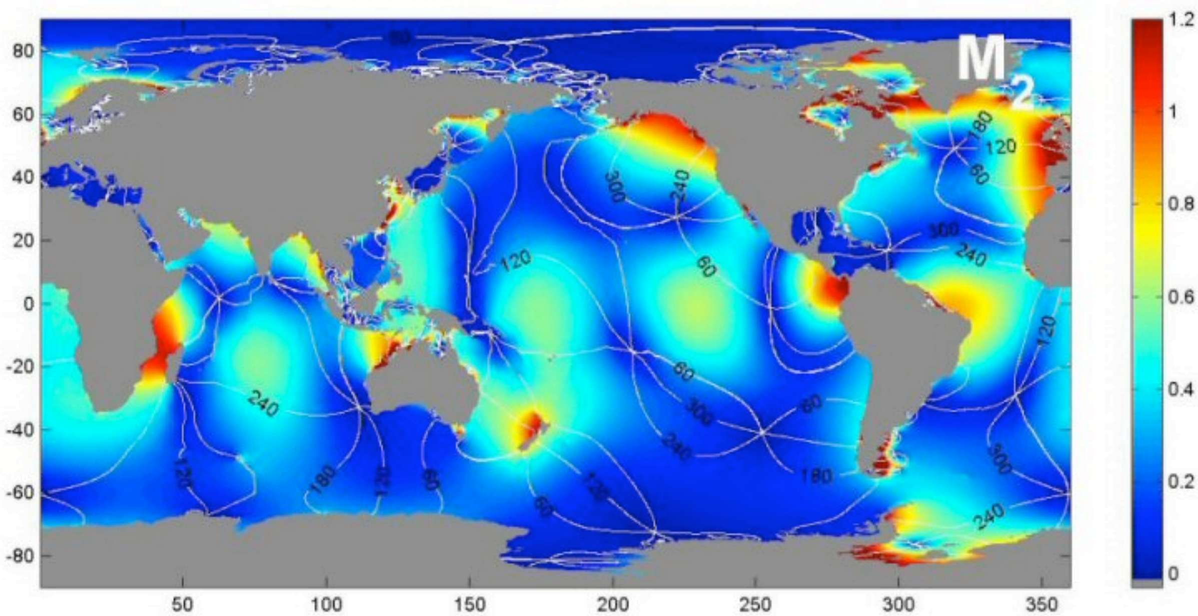
A. deep-water form of surface gravity wave equations
   1. harmonic solutions -> **dispersion** (**Figure** to left)
   2. phase & group velocities

B. particle path; streamline; Stokes Drift; energy; pressure at the seafloor

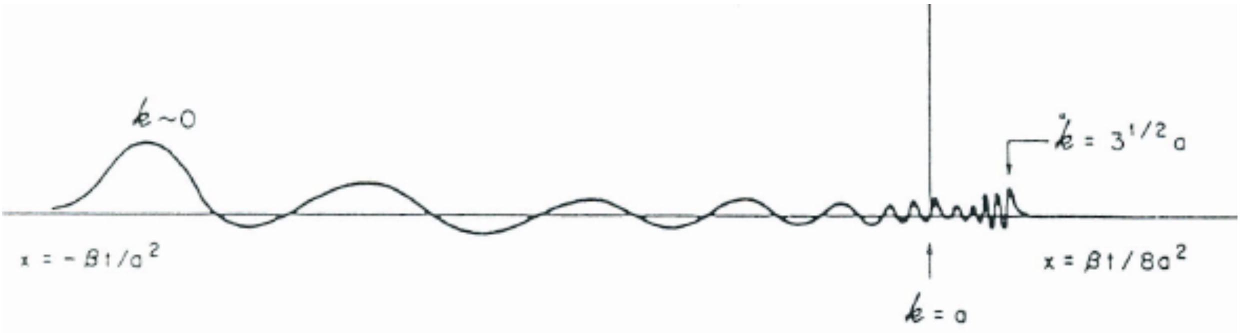
V. Waves with Rotation (still 2-D) - Gravity

A. tangent-plane coordinates; f-plane approximation
   1. `traditional' approximation; geostrophic balance

B. Poincare-Sverdrup Waves (dispersive gravity-rotation waves)
   1. potential energy (PE) vs. kinetic energy (KE) content
   2. Rossby radius; dominance of gravity or rotation depending on wavelength
   3. inertial motion
   4. boundary effects; reflection; Kelvin waves
      a. channels; gulfs; basins
   5. **ocean tides** (**Figure** below shows the M_2 constituent's amplitude in meters and phase)



G. Egbert & L. Erofeeva - http://volkov.oce.orst.edu/tides/global.html

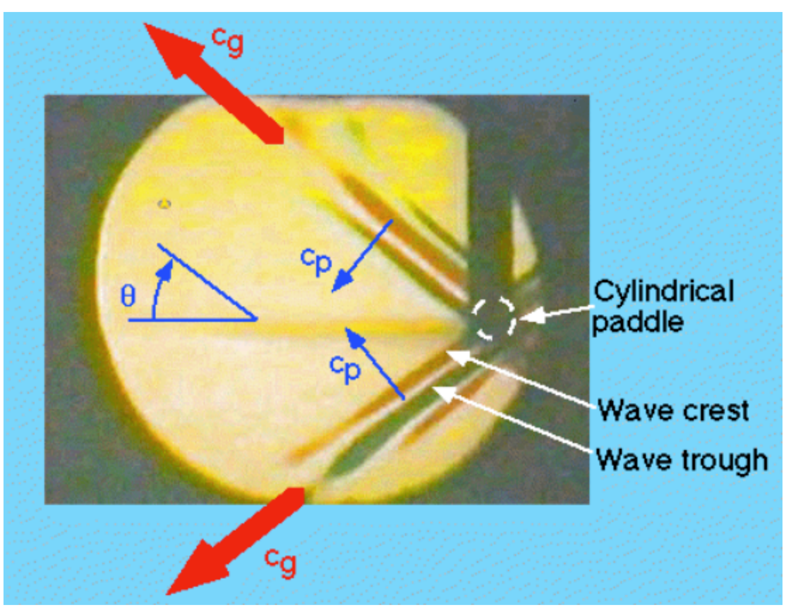


J. Pedlosky, *Geophysical Fluid Dynamics*, Springer, 1992

VI. Waves with Rotation (still 2-D) - Vorticity

A. Rossby Waves (vorticity waves)
  1. beta-plane approximation
  2. meaning of vorticity & divergence
  3. equations for vorticity & divergence from Laplace's Tidal Equations
  4. **dispersion** (**Figure** above); westward phase propagation
  5. physical interpretation of Rossby waves
     a. PE vs. KE; contrast with Sverdrup waves
  6. relation to quasi-geostrophic (QG) equations
  7. limiting forms of Rossby waves
  8. reflection; basin modes

B. Potential Vorticity Conservation in the Shallow-Water Eqns.
  1. meaning of potential vorticity
  2. effect of sloping bottom
     a. derivation of topographic vorticity waves



B. Ruddick - http://www.phys.ocean.dal.ca/programs/doubdiff/demos/IW1-Lowfrequency.html

VII. Waves with Stratification (3-D waves)

A. Uniform Stratification
  1. separation of variables; equivalent depth for hydrostatic waves
  2. external (barotropic) & **internal** (baroclinic) modes (**Figure** shows forced internal waves)

OCN660 - Student Learning Outcomes

At the conclusion of this course, students should be able to accomplish the following:

- articulate the concepts of free oscillations, forced motions, transients, and resonance;
- articulate the balance of forces associated with each of the five fundamental types of waves (acoustic, capillary, gravity, inertial, vorticity) that are found in a homogeneous flat-bottomed ocean;
- derive the dispersion relation, phase velocity and group velocity, given the equation of motion for any type of oceanic wave, and explain their meanings;
- employ a dispersion relation to derive spatial scales, given a frequency of oscillation and relevant environmental parameters;
- explain features of the ocean's tides, in both marginal seas and the open ocean, in terms of the known structures of the different kinds of rotation-modified gravity waves;
- define and calculate the Rossby Radius, and explain its importance to gravity, inertial and vorticity waves in the ocean;
- derive and explain the relative balance of potential and kinetic energies for each of the five fundamental types of oceanic waves in a flat-bottomed ocean; and,
- read and understand the classic upper level texts on ocean wave kinematics and dynamics, such as Kinsman's *Wind Waves*, Phillips' *Dynamics of the Upper Ocean*, LeBlond and Mysak's *Waves in the Ocean*, and Gill's *Atmosphere-Ocean Dynamics*.

OCN660 - Prerequisites

This course is designed for first-year graduate students pursuing higher degrees in physical oceanography. It is expected that students will have a solid familiarity with the following: calculus concepts (including differentiation in several variables and multiple integrals), complex variables, and ordinary differential equations to second order. Familiarity with partial differential equations, Fourier Series, and vector calculus is desirable. The well-prepared student will already have had an introductory course in fluid mechanics, but, if not, the student should at least be enrolled concurrently in fluid mechanics; the Dept. of Oceanography's OCN662 - Marine Hydrodynamics - is recommended.

Can you spot the lighthouse keeper?

Yes, he survived. He ducked inside just at the last second before this 20 meter wave completely engulfed the Le Jument lighthouse in Brittany, France. This lighthouse is regularly pummeled by such waves during the winter.

photo: Jean Guichard

Administrative Notice: *The University of Hawai'i is committed to providing a learning, working and living environment that promotes personal integrity, civility, and mutual respect and is free of all forms of sex discrimination and gender-based violence, including sexual assault, sexual harassment, gender-based harassment, domestic violence, dating violence, and stalking. If you or someone you know is experiencing any of these, the University has staff and resources on your campus to support and assist you. Staff can also direct you to resources that are in the community. Here are some of your options:*

As members of the University faculty, your instructors are required to immediately report any incident of potential sex discrimination or gender-based violence to the campus Title IX Coordinator*. Although the Title IX Coordinator and your instructors cannot guarantee confidentiality, you will still have options about how your case will be handled. Our goal is to make sure you are aware of the range of options available to you and have access to the resources and support you need.*

If you wish to remain ANONYMOUS, speak with someone CONFIDENTIALLY, or would like to receive information and support in a CONFIDENTIAL setting, contact the Title IX office directly (Hawai'i Hall 124, 2500 Campus Road (808) 956-2299) or use the ***confidential resources available here****: http://www.manoa.hawaii.edu/titleix/resources.html#confidential*

If you wish to directly REPORT an incident of sex discrimination or gender-based violence including sexual assault, sexual harassment, gender-based harassment, domestic violence, dating violence or stalking as well as receive information and support, contact: Dee Uwono Title IX Coordinator (808) 956-2299 t9uhm@hawaii.edu