

SMS 303: Integrative Marine Sciences III

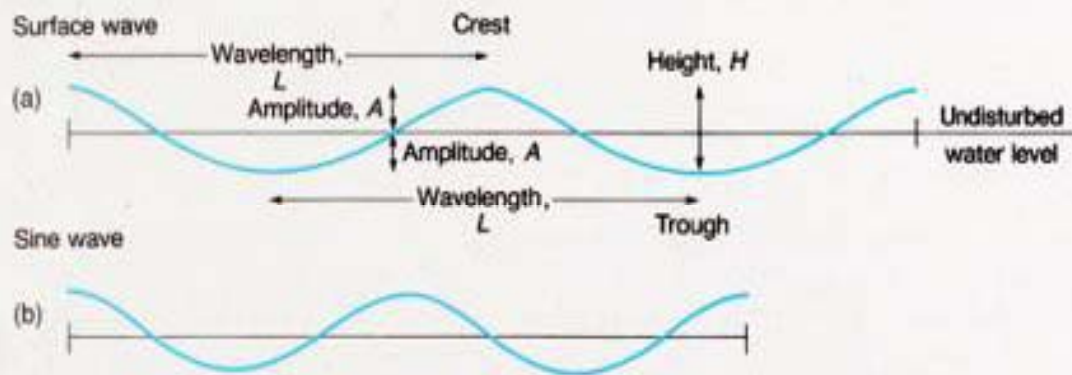
- Instructor: E. Boss, TA: A. Palacz
emmanuel.boss@maine.edu, 581-4378
- 5 weeks & topics: ~~diffusion~~, ~~mixing~~, ~~Coriolis~~, waves and tides.
- Calculus/math is a tool science majors should be expected to use. Don't think you are done with it...
- Much about waves is covered in 302. I will try to enhance it here.

• Review: Waves

- What characterizes waves:

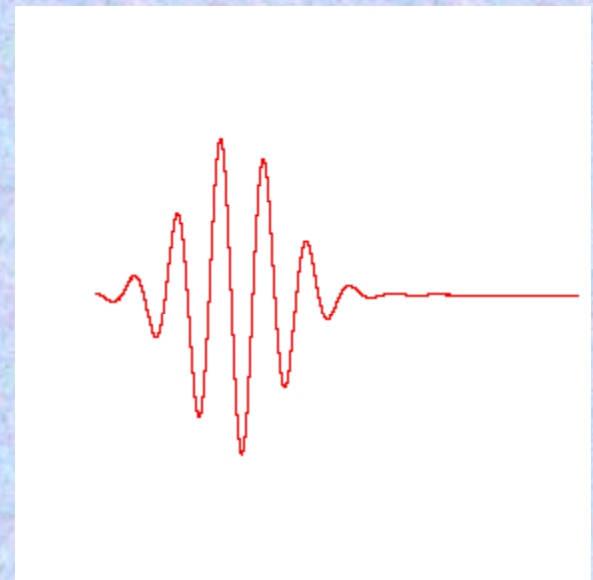
- Periodic behavior in time or space.
- Examples: ???
- We will focus on *gravity waves* (where gravity is the restoring force).

Anatomy of a wave:



$$A \sin\{2\pi(x/\lambda - t/T)\} + B \cos\{2\pi(x/\lambda - t/T)\} = C \sin\{2\pi(x/\lambda - t/T) + \phi\}$$

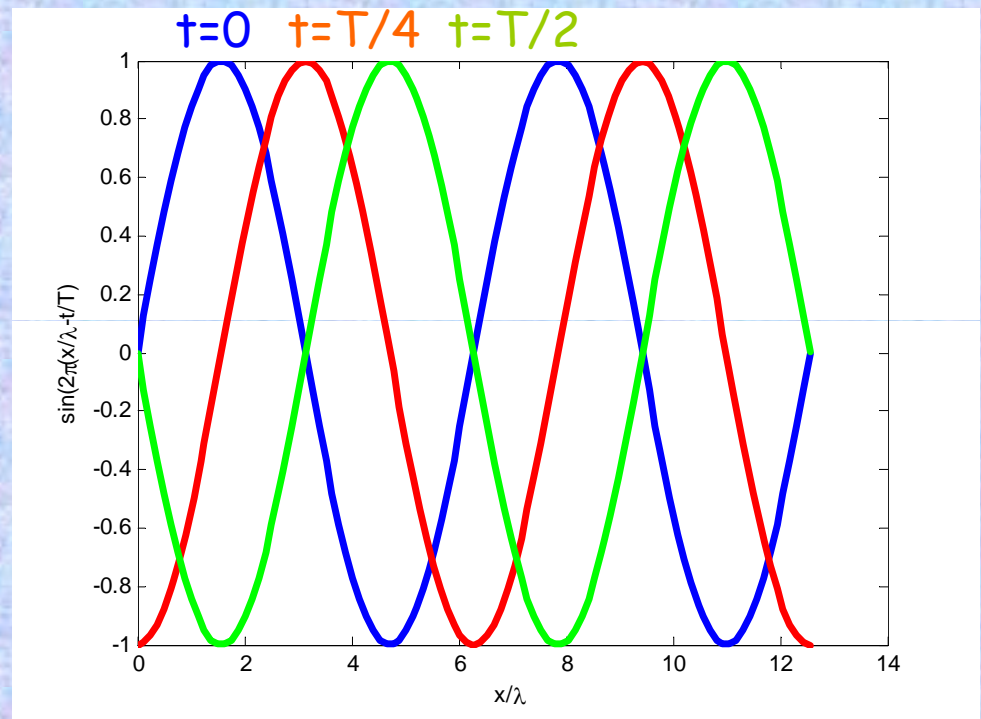
Wave packet:



- Wave propagation:
 - Plane wave propagating in positive x direction:

$$h = A \sin\{2\pi(x/\lambda - t/T) + \phi\}$$

$$\text{Phase: } 2\pi(x/\lambda - t/T) + \phi$$



- Speed of propagation:
 - Phase speed (celerity): $c = \lambda/T$
 - Group speed-speed of energy propagation.
 - Not necessarily the same (or even in the same direction).

• Deep and shallow-water waves (H-water depth):

-Different behavior

Deep water waves: $\lambda < 2H$, $C = [g\lambda/2\pi]^{1/2}$

Different waves (λ) have different speed-
dispersion.

$$c_g = 0.5C$$

Shallow water waves: $\lambda > 20H$, $C = [gH]^{1/2}$

Different waves have the same speed-
non-dispersive.

$$c_g = C$$

In class shallow water wave speed exercise

Example: Kelvin wake.



From wiki-media

Dead-water:



Movie

Nansen, 1893:

"When caught in dead water Fram appeared to be held back, as if by some mysterious force, and she did not always answer the helm. In calm weather, with a light cargo, Fram was capable of 6 to 7 knots. When in dead water she was unable to make 1.5 knots. We made loops in our course, turned sometimes right around, tried all sorts of antics to get clear of it, but to very little purpose." Problem solved by Ekman, 1904.

Note: since information cannot propagate faster than the wave speed, information regarding sudden events are also limited by this speed (think sonic booms).

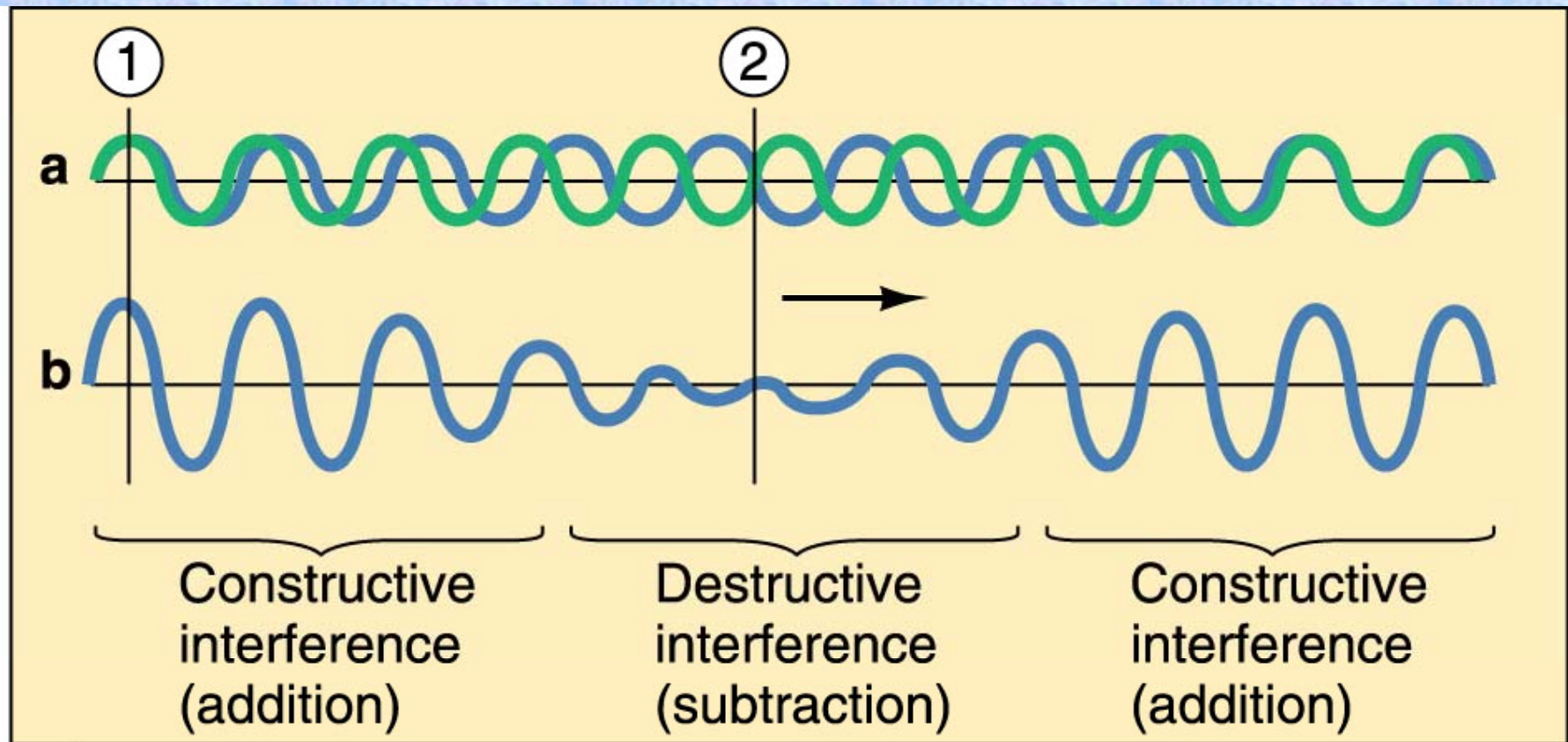
Examples:

Tsunami - <http://www.youtube.com/watch?v=oakG2vDRIKq>

Dam break - http://www.youtube.com/watch?v=-e6maU1xJ_A

El-nino - <http://www.youtube.com/watch?v=PCT49t648JA>

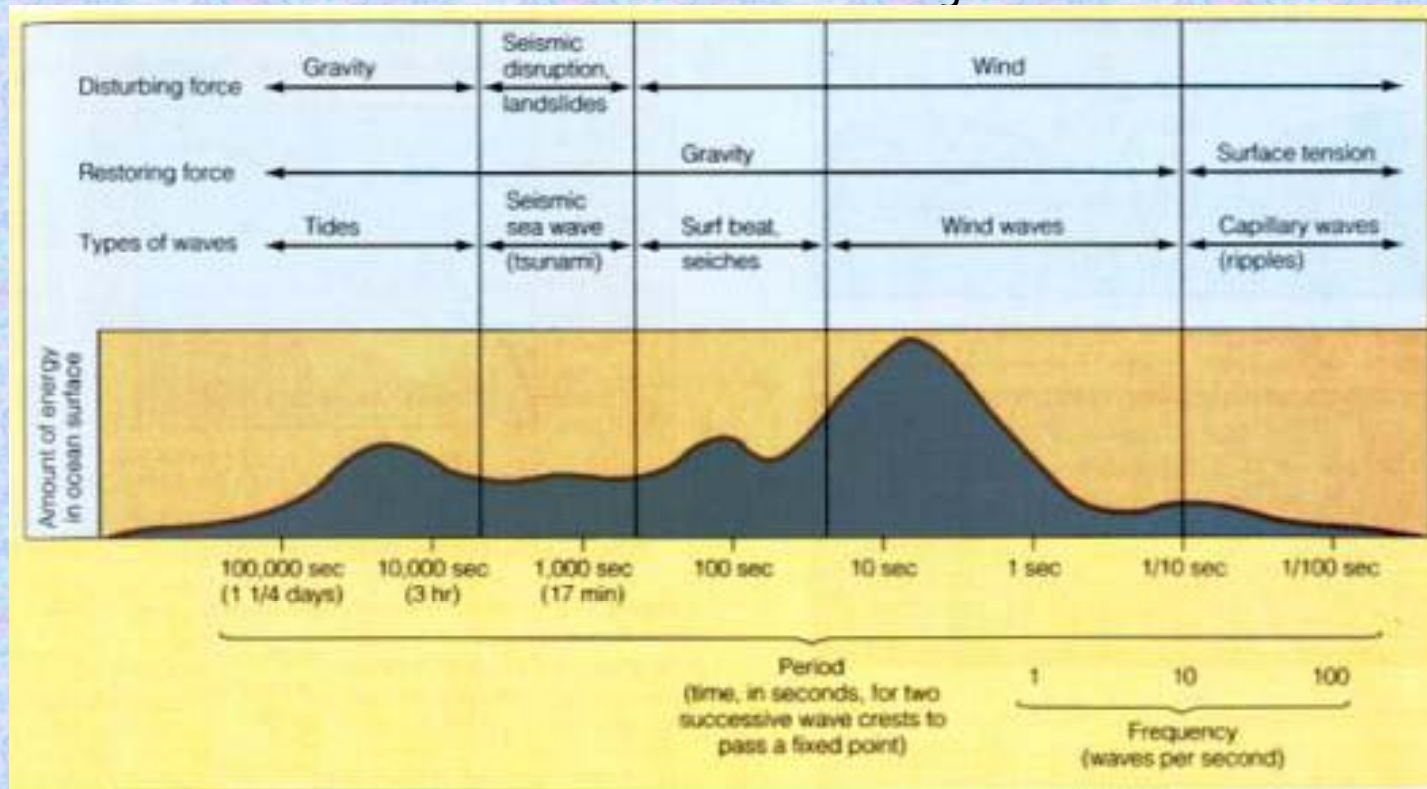
- Surface: superposition of many waves:



Demo: beating.

- Wave energy

- $E = (\rho g a^2) / 2$, per L^2 both kinetic and potential
- Propagate with c_g
- energy flux (per L of beach): $c_g E$



Class exercise:

How much energy flux is generated by 1m high 8s deep wind waves per 1m of wave front?

Making energy from waves:

Wave generated wind:

<http://www.youtube.com/watch?v=gcStpg3i5V8>

Oyster and snakes:

<http://www.youtube.com/watch?v=90AcxxwoPu0&feature=fvw>

<http://www.youtube.com/watch?v=u-9P2VfIRWU&feature=related>

<http://www.youtube.com/watch?v=F0mzrbfzUpM&NR=1>

Aquabuoy:

<http://www.youtube.com/watch?v=74IVv3ocUGY&feature=related>

<http://www.youtube.com/watch?v=XIIM3k6QyQ&feature=related>

Coastal generator:

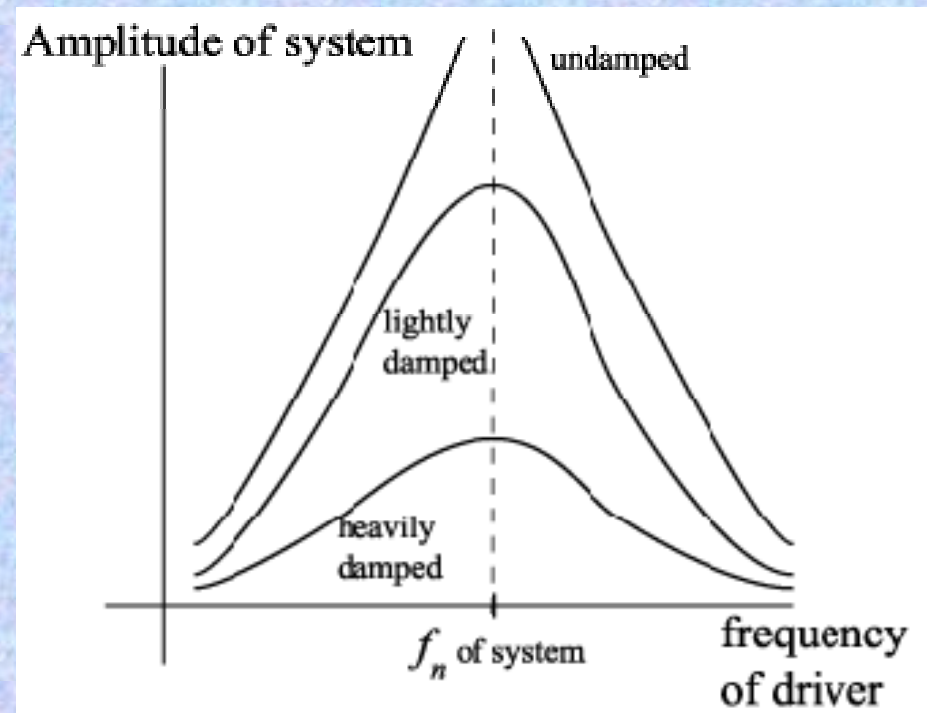
<http://www.youtube.com/watch?v=RZFvHofl3qo&feature=related>

How to build your own wave generator:

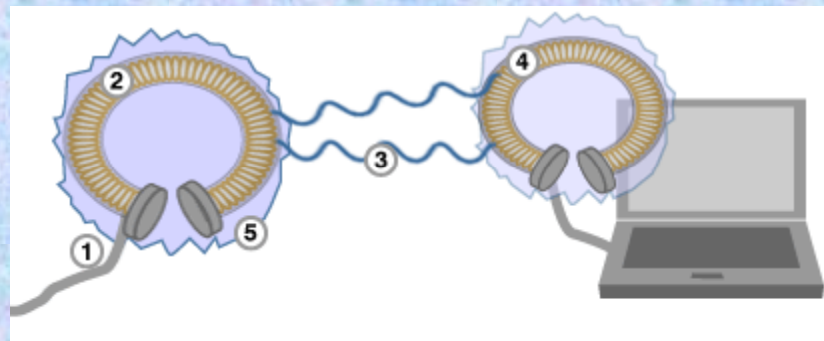
<http://www.youtube.com/watch?v=qkaPAw3sOek&NR=1>

Resonance

- Physical construct have natural frequencies based on their dimensions (think about musical instruments).
- Forcing at these frequencies (among others) result in large response at the resonant (s) frequency (ies).

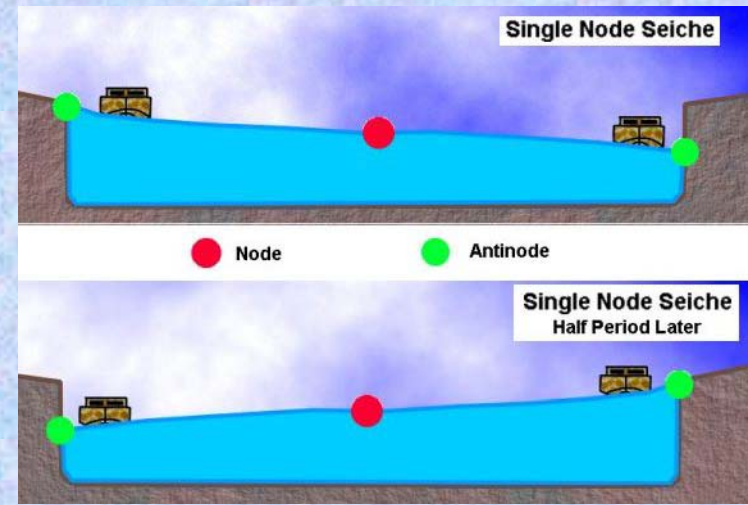
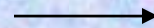
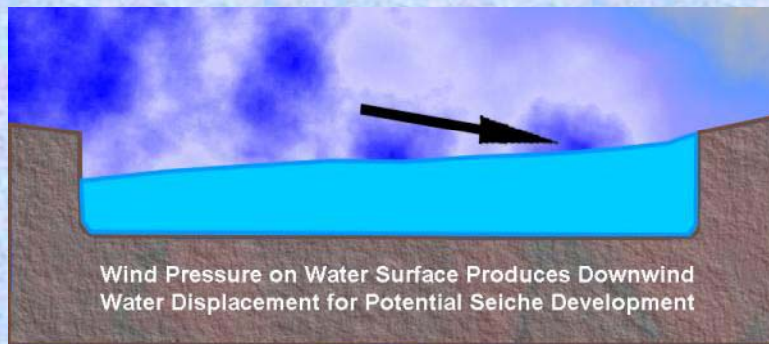


Breaking news:



Resonance demos

Example: **Seiches** - the natural modes of a basin



<http://www.islandnet.com/~see/weather/almanac/arc2004/alm04jun.htm>

[Seiche calculator](http://www.coastal.udel.edu/faculty/rad/seiche.html) (<http://www.coastal.udel.edu/faculty/rad/seiche.html>)

In an enclosed basin: the 1st (usually dominant) mode is half wavelength long.

In a basin open at one side: the 1st mode is a quarter wavelength long.

The seiche is the 'natural' wave of the basin.

How do we determine the period of a seiche for a basin of depth H and length L ?

Doppler shift

- Change in frequency due to the motion of the source and/or the receiver
- Allows for determination of movement of target.

Stationary source:

$$f = c/\lambda$$

$$f' = (c \pm u_r) / \lambda$$

$$\rightarrow \Delta f = \pm u_r / \lambda = f u_r / c$$

Stationary receiver:

$$\Delta f = \pm f u_s / (c \pm u_s) \sim \pm f u_s / c$$

Both moving:

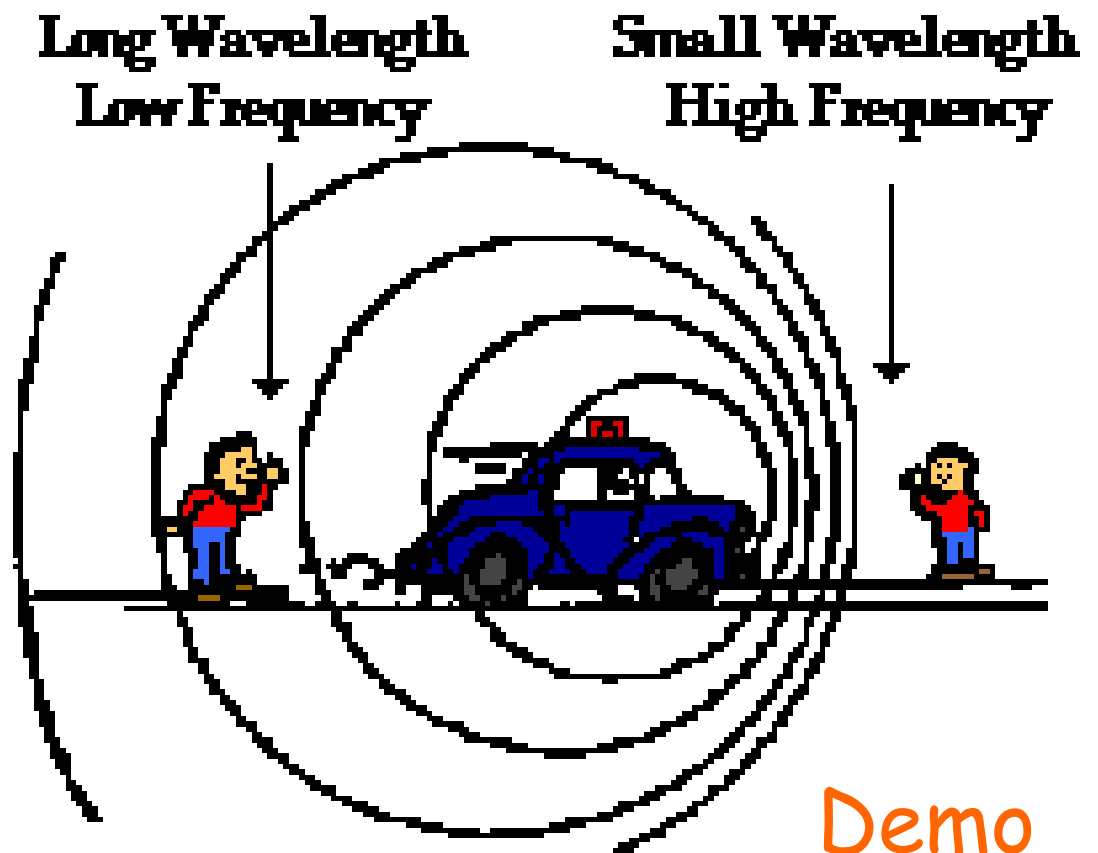
$$\Delta f \sim f (\pm u_s \pm u_r) / c$$

c-speed

λ -wavelength

f=frequency

$u_{r,s}$ -speed of receiver or source



The Doppler Effect for a moving sound source

Most common method to measure currents

- **Hull speed**

- Speed of wave formed at the surface by moving an object (boat, duck) = $(gL/(2\pi))^{1/2}$
- Going faster than hull speed results in excessive drag.

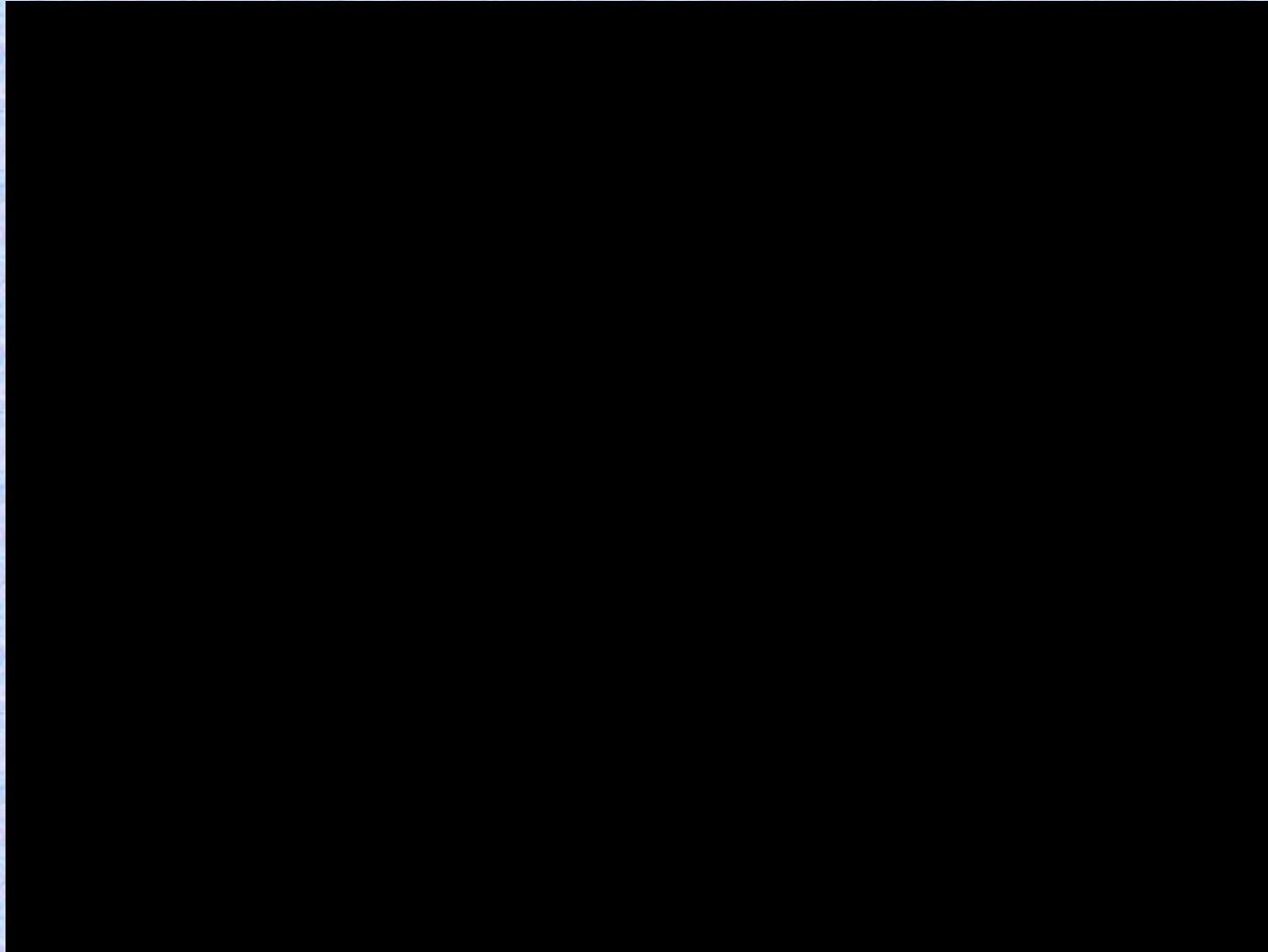


A boat moving at slow speeds creates a series of waves with short wavelengths



A boat moving at higher speeds will create longer waves. At a critical speed, called the Hull Speed, the length of the wave will equal the length of the boat, and to go faster, the boat must work against gravity to climb out of the trough of its own wave. Powerboats can exceed Hull Speed by climbing out of the trough and skimming (hydroplaning) on top of the water, but human powered boats cannot.

The strangest water wave, **the internal wave**:



Continuously stratified fluid. For more:
http://www.gfd-dennou.org/library/gfd_exp/exp_e/index.htm