What is Hydrodynamics?

- **Hydrodynamics v. Aerodynamics**
  - Water is almost 1000 times denser than air!

- **Marine Hydrodynamics**
  - Design of underwater vehicles, ships, platforms
  - Waves, wave energy,
  - External flows around ships, hydrofoils, propellers, etc.
  - Added Mass!
  - Flow-structure interactions
Fluid Properties @20°C

- **Air**
  - Density
    \[ \rho = 1.2 \text{ kg/m}^3 \]
  - Dynamic Viscosity
    \[ \mu = 1.82 \times 10^{-5} \text{ N·s/m}^2 \]
  - Kinematic Viscosity
    \[ \nu = \frac{\mu}{\rho} = 1.51 \times 10^{-5} \text{ m}^2/\text{s} \]

- **Water**
  - Density
    \[ \rho = 998 \text{ kg/m}^3 \text{ (fresh water)} \]
    \[ \rho = 1025 \text{ kg/m}^3 \text{ (seawater)} \]
  - Dynamic Viscosity
    \[ \mu = 1.0 \times 10^{-3} \text{ N·s/m}^2 \]
  - Kinematic Viscosity
    \[ \nu = 1 \times 10^{-6} \text{ m}^2/\text{s} \]

Ocean Exploration & Hydrodynamics

- 70-75% of the earth’s surface is covered by water.
- The earth’s oceans are one of our least explored resources.
- Many exciting discoveries lie waiting in the deep: such as Food, medicines, energy, and water.
- Good engineering is needed to advance current ocean exploration capabilities and to assure that our ocean resources will persist for generations to come.
- Understanding marine hydrodynamics can help us to design better ocean vessels and to understand physical ocean processes.

MIT Dept. Mechanical Engineering, 2005
Offshore Engineering

The offshore platform must be designed to simultaneously withstand hurricane force waves and winds.

The Ursa unit is located approximately 130 miles south-east of New Orleans.

Petrogas Rig Sinking off Brazil Due to explosion onboard

Genesis Spar Platform
**Biologically Inspired Vehicles?!?**

- The study of fish and other aquatic animals has led to engineering designs for underwater vehicles inspired by these creatures amazing ability to exist in the ocean.
- This mimicking of nature is widespread through science and engineering and is referred to as biomimetics...

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**Ocean Waves**
Random Ocean Waves

Wave Energy Spectra

Figure 1. Wave energy spectra. Red text indicates wave generation mechanisms and blue text indicates damping/attenuation forces.
Wake Instability

Hydrodynamic Forces on Vessels

- Linear wave theory
- Added mass!!
- Wave forces on bodies
- Viscous forces on bodies:
  - Skin Friction Drag
  - Vortex shedding, Vortex induced vibrations
- Viscous damping
Ship Motions

Linear Motions
\[ x_1 = \text{surge} \]
\[ x_2 = \text{sway} \]
\[ x_3 = \text{heave} \]

Angular Motions
\[ x_4 = \text{roll} \]
\[ x_5 = \text{pitch} \]
\[ x_6 = \text{yaw} \]

Right hand rule rules!

Nomenclature

- Length on Waterline (LOW)
- Beam (width of vessel at widest point)
- Midships (center of ship)
- Draft (depth of the keel below the water)
- Keel = part of the vessel extending below the hull
Course Organization

• Instructor: Professor Alexandra H. Techet
  – Email: ahtechet@mit.edu
  – Office: 5-326c
  – Phone: 617-452-2266 (x2-2266)
• TA: Brenden Epps
  – Email: bepps@mit.edu
  – Office: 33-409
  – Phone: TBA
• Schedule
  – Lecture: T/R 1-2 :30pm Room: 1-371
  – Lab/Rec.: Fri 9a-12p Room: TBA
• Course Website

Syllabus

• Part I: Introduction to Marine Hydrodynamics
  – Basic Fluid Properties
  – Hydrostatic Pressure
  – Basic Principles of Hydrodynamics
• Part II: Free Surface Waves and Wave Forces on Offshore Structures and Vehicles
  – Linear Wave Theory: Boundary Value Problem; Simplifying assumptions
  – Dispersion Relationship
  – Unsteady Bernoulli’s Equation, Dynamic Pressure
  – Incident wave forces on bodies
  – Added Mass, Damping, & Hydrostatic restoring coefficients (Strip theory)
  – Equations of motion for Seakeeping; natural frequency
Syllabus

• Part III: Viscous Flows and Free Surface Flows
  – Viscous Lift and Drag;
  – Drag and resistance of streamlines and bluff bodies
  – Vortex Induced Vibrations (VIV); Morrison’s Equation (Offshore Platforms)
  – Ship Resistance Testing
  – Rudders and Propellers, Cavitation and Flow Noise
  – Navier Stokes Equations: Separated Flows and Boundary Layers *

• Part IV: Geophysical Fluid Dynamics*
  – Major ocean circulations and geostrophic flows;
  – Heat balance in the ocean;
  – Influence of wind stress
  – Coriolis force, Tidal forces, geostrophic currents
  – Equations of motion

* time permitting

Grading

• Grading Policy:
  – Homework: 15%
  – Laboratory: 20%
  – 2 In-class Exams: 30%
  – Final Exam: 35%

• Exam #1 In class: 10/6 Thursday
• Exam #2 In class: 11/17 Thursday
• Final Exam: TBA
Labs

• Lab Safety Brief
  – Tomorrow 9am in room 5-025
• Lab #1 Added Mass:
  – Friday 9/23 in 5-025 EHL
• Lab #2 Waves
  – Friday 10/14 in 48-015 Towtank
• Lab #3 Ship Resistance
  – Friday 11/4 in 48-015 Towtank
• Lab #4 Group Project
  – TBA, reports due 12/2, presentations 12/9
• Labs due on the following THURSDAY in class.

Recitations

• During non-lab weeks recitations will be held Fridays from 9-11 am in Room 5-234.
• These recitations will cover additional examples and course material as necessary.
• Additional exam reviews may also be scheduled by the TA.
Homeworks

- Weekly problem sets will be assigned and are due the following week unless otherwise noted.
- Homework solutions are expected to be the result of individual effort.
- Group discussions of the concepts covered on the homework and review of the course material is encouraged.
- HW handed out on Tuesdays, due the following Tuesday.