Meccanica dei Fluidi

INIZIO LEZIONE ORE 11:15

Meccanica dei Fluidi

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Dipartimento di Ingegneria Civile,
Chimica e Ambientale (DICCA)

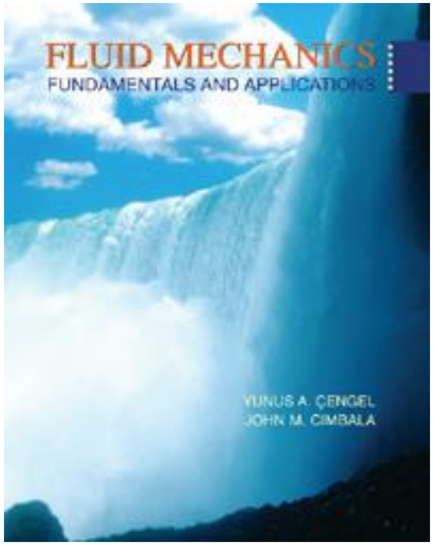
Secondo Semestre 2023/2024

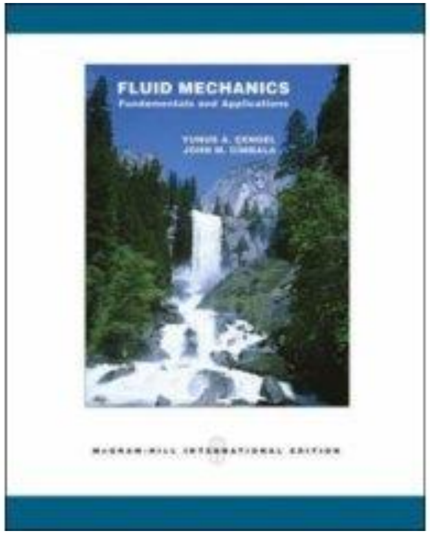
Textbook

- **Fluid Mechanics. Fundamentals and Applications**, McGraw-Hill, 2006
  Yunus A. Çengal (Univ. Nevada, Reno) and John M. Cimbala (Penn State)
  Includes DVD with movies created at PSU by Prof. Gary Settles

- Available at
  - Amazon.com (paperback)
  - Libreria Frasconi, Corso Gastaldi 193r

- A version in Italian exists …





Textbook

- **Fundamentals of Fluid Mechanics**, Wiley, 2012
  Bruce R. Munson (Iowa State), Theodore H. Okiishi (Iowa State), Wade W. Huebsch (West Virginia), and Alric P. Rothmayer (Iowa State)

- Available at
  - Amazon.com (paperback)
  - Libreria Frasconi, Corso Gastaldi 193r

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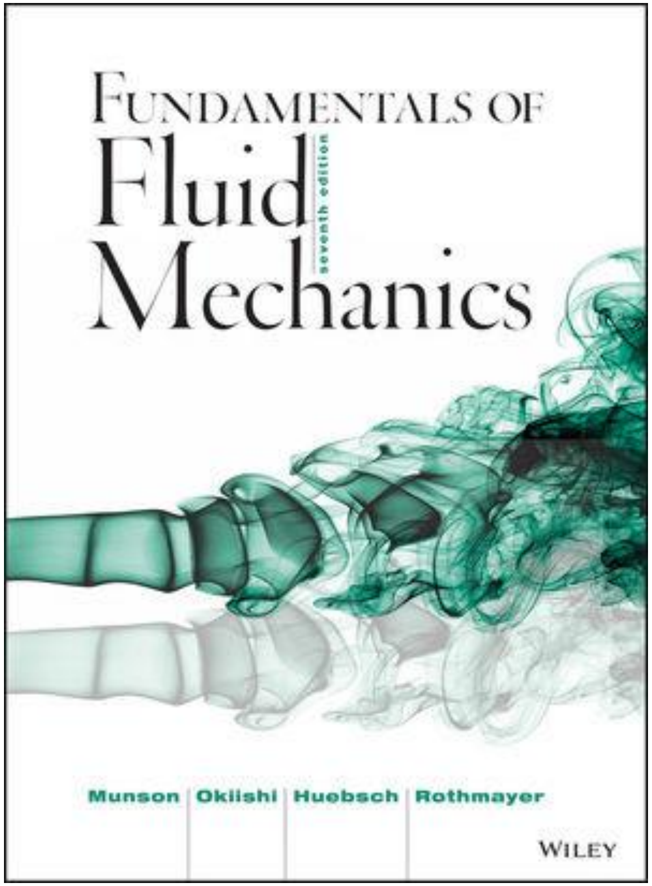
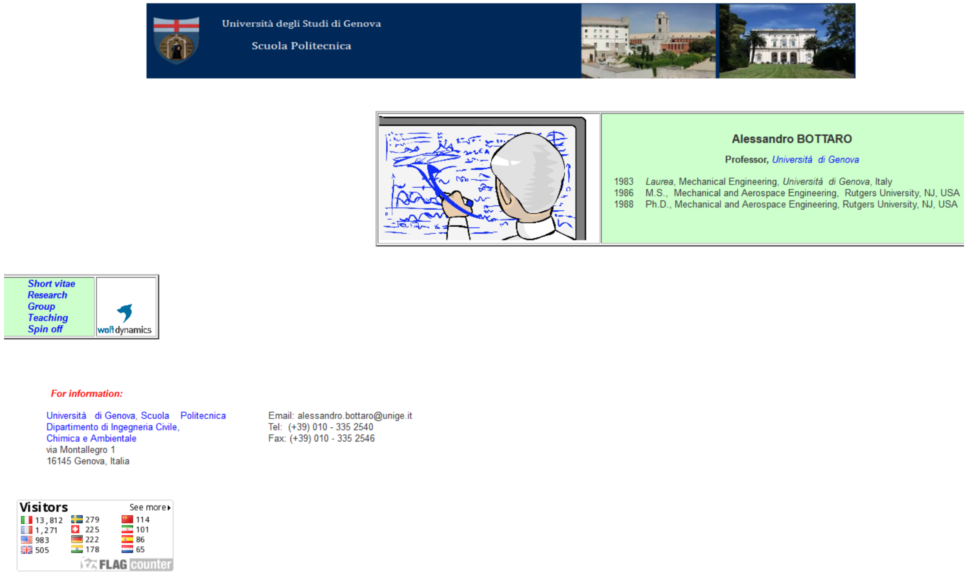


Web site

- All class material and announcements will be posted on aulaweb. There is also a course web site: www3.dicca.unige.it/bottaro/fmnew.html
  - Syllabus
  - Schedule/Calendar
  - Lecture notes
  - Message boards
  - Past mid terms and finals
  - Exam rules
  - Grades



Web site

Università degli Studi di Genova

Scuola Politecnica

Meccanica dei Fluidi 1 ME (37656)

INFORMAZIONI IMPORTANTI:

GLI ESAMI SONO "CLOSED BOOKS"; GLI STUDENTI POTRANNO STAMPARSI E USARE QUESTO FORMULARIO (STAMPATO FRONTE-RETRO) PER IL PRIMO COMPITINO, OPPURE QUEST'ALTRO PER IL SECONDO, PIU' IL DIAGRAMMA DI MOODY.

SOLO IL MATERIALE MESSO A DISPOSIZIONE DAL DOCENTE E' AMMESSO.

Prossimo appello di esame di Meccanica dei Fluidi:
Scritto, ore 14 del 17 gennaio 2019, aula A11 (Villa Cambiaso)
Iscrizione con email al docente. Orale a seguire.

- Finalità del corso, programma, modalità di svolgimento dell'esame, testi
- Appelli di esame per gli studenti di Ingegneria Meccanica
- Materiale didattico (lucidi proiettati in corso, basati sul corso sviluppato a Penn State, State College, PA, da Eric G. Paterson)
  - Introduction
  - Chapter 1
  - Chapter 2
  - Chapter 3, additional material on the concept of metacenter of a ship, from the lecture notes on the geometry of floating bodies by D. Di Blasi, University of Messina (in Italian)
  - Chapter 4
  - Chapter 5
  - Chapter 6
  - Chapter 7, additional material on dimensional analysis, from the lecture notes in fluid dynamics by Laura Landò Rebaudengo and Giulio Scarsi, University of Genova (in Italian)
  - Chapter 8 (have a look also at the interesting paper by Sznitman et al. (2013), on scaling and dimensional analysis).
  - Chapter 9
  - Chapter 10, plus a few notes on the Blasius boundary layer. and a short course on microhydrodynamics.
  - Chapter 11, plus a short course on transition to turbulence in shear flows.

Web site

Esami e compitini passati:

Compitini corretti (Fila A, Fila B, Fila C, Fila D, Fila E) del 13.11.2013.

Compitini corretti del 18.12.2013.

Compitini di recupero del 20.01.2014 (correzione del primo e del secondo compitino).

Compitini corretti del 3.4.2015.

Compitini corretti del 3.6.2015.

Compitini corretti del 7.4.2016.

Compitini corretti del 1.6.2016.

Compitini corretti del 19.5.2017

Compitini corretti del 1.6.2017.

Compitini corretti del 7 giugno 2017. .

Compitini corretti del 5 aprile 2018 e del 9 aprile 2018.

Compitini corretti 29 maggio 2018 e del 1 giugno 2018 con voti.

Dopo che entrambi i compitini sono stati valutati,
(1) si deve informare il docente nel caso in cui NON si voglia la registrazione del voto medio finale (se ad esempio voleste migliorarlo) e
(2) E' OBBLIGATORIO COMPILARE IL MODULO DI VALUTAZIONE DELL'INSEGNAMENTO!

In assenza di comunicazione da parte da parte dello studente relativamente alla registrazione - entro una settimana dal momento in cui i voti sono stati inseriti su questa pagina - TUTTI i voti finali superiori o uguali a 18 saranno registrati.

Regole di esame:

- Lo studente che abbia riportato nei due compitini proposti durante il semestre una votazione media superiore o uguale a 15 è ammesso alla prova orale. Se la votazione media dei compitini è superiore o uguale a 18 (con un minimo di 12 in ambedue le prove), la prova orale può essere evitata; in tal caso la votazione finale è la votazione media delle prove scritte.
- Lo studente che abbia riportato nei compitini una votazione media superiore al 29 (incluso) può decidere di tentare la prova orale per ottenere la votazione finale di 30/30 e lode.
- Lo studente che decide di sostenere la prova orale può migliorare o peggiorare la votazione dello scritto.
- Lo studente che decide di non fare i compitini o che non riceve una media soddisfacente nei compitini può affrontare un esame scritto su tutta la materia durante le normali sessioni di esame; in tal caso l'orale è obbligatorio.
- Nella determinazione del risultato finale dello scritto la votazione sara' arrotondata al numero intero piu' vicino (es. 22.45 ➔ 22). Se il risultato dello scritto risultasse esattamente a metà tra due cifre intere, la votazione finale sarà arrotondato al numero intero superiore (es. 22.50 ➔ 23).

►►►►►► ►► ►► Fino a 3 (tre) BONUS POINTS aggiunti alla media finale per l' UNIGE-ME Fluid Photo/Video Competition ◄ ◄◄◄◄◄◄◄◄◄

Per sostenere l'esame completo è indispensabile iscriversi inviando una e-mail al docente (la regola non si applica per i compitini svolti durante il semestre).

Web site

- All class material and announcements will be posted on aulaweb. There is also a course web site: www.dicca.unige.it/bottaro/fmnew.html
  - Syllabus
  - Schedule/Calendar
  - Lecture notes
  - Message boards
  - Past mid terms and finals
  - Exam rules
  - Grades
- Other interesting links can be found at

  www.dicca.unige.it/bottaro/teaching.html
  - Roberto Verzicco
  - Jean Pierre Petit

IL VOLO, Jean Pierre Petit

Grading

- Mid-term exam: 50%
- Final exam: 50%

} **Strongly encouraged!!!!**

- For those doing "mid-term + final" the oral exam is optional (to be done in June/July, 2024)
  - The grade of the oral exam (required for those with a grade G with $15 \leq G < 18$) averages out with the written tests. Cut-off grade: 12.
- For those not doing a "mid-term+final":
  - Comprehensive written exam + compulsory oral exam

Partial exams date

- Mid-term exam: April 9th, 2024 11:00 – 14:00
- Final exam: May 30th, 2024 15:00 – 18:00

Both midterm and final will be held in B1

Dates of the “regular” exam

June 6th, 2024	2pm
June 21st, 2024	2pm
July 19th, 2024	9am
September 13th, 2024	9am

We meet 15 minutes ahead of schedule to check ID’s. Students must formally register for the exam at least 5 days before the exam date. The exam will consist of a **written test** followed by an **oral** exam for those who have achieved a score of at least 15/30 in the written part.

Closed books!

Exam policies

- Philosophy
  - Fluid mechanics is not easy …
  - One of the best ways to learn something is through practice and repetition
  - Therefore, exercises are extremely important in this class!
  - If you study and understand the exercises in the book and elsewhere, you should not have to struggle with the exam/quiz

BONUS POINTS!

The *UNIGE-ME fluid photo/video competition*

- Keep an eye on fluid flow phenomena, and take pictures/videos!
- Send me your best original shots/videos, with indications of date/location/brief description (max 100 words) of the phenomenon you are observing.
- The best photographs/videos will gain **3/2/1** points to be added to your final grade.
- Only one entry per student. No group entries.

BONUS!!

The *UNIGE-ME fluid photo/video competition*

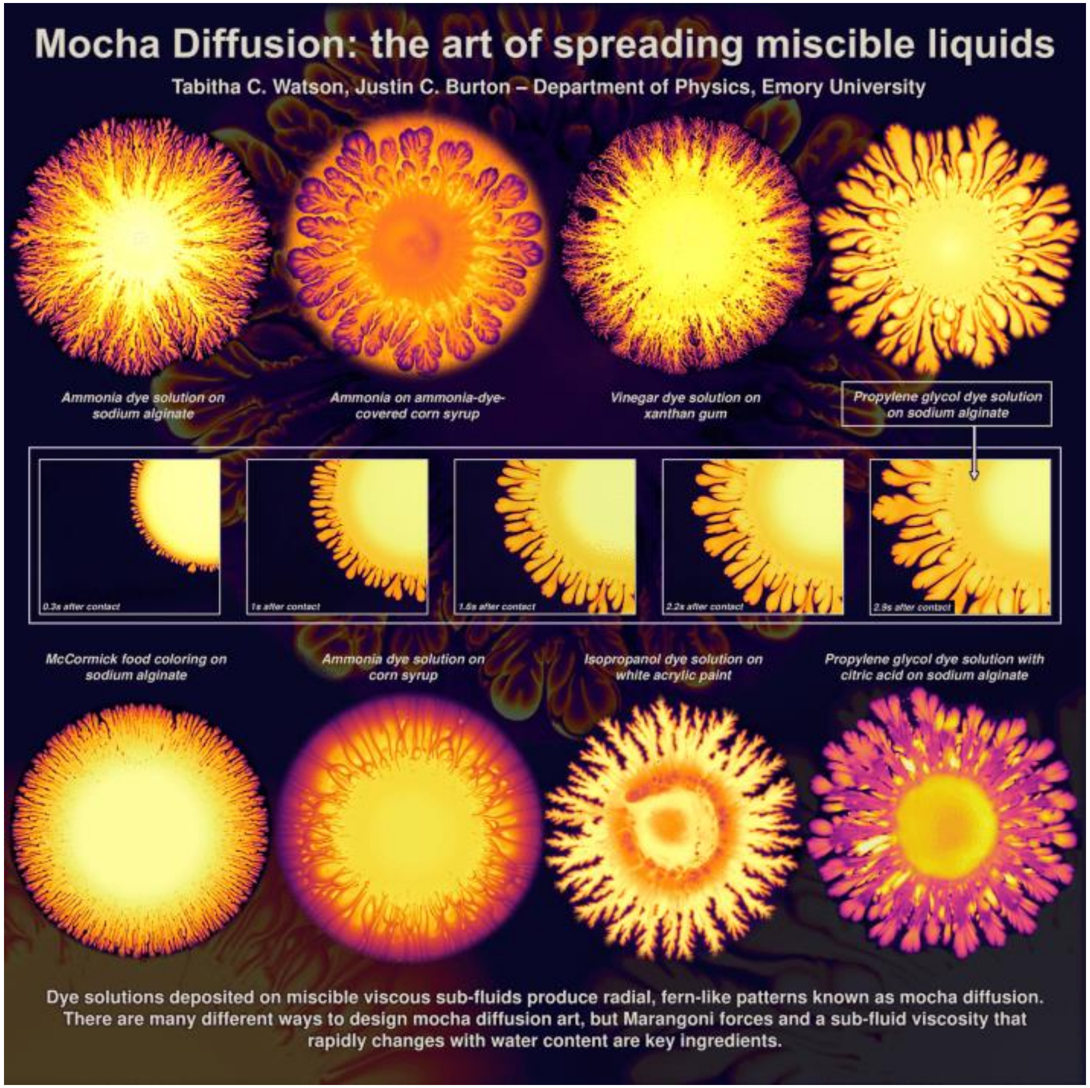
- All photos/videos will be judged by the instructors on the basis of three criteria:
  - **aesthetic appeal**,
  - **uniqueness of the phenomenon**, and
  - **quality of explanation of the observed phenomenon**.
- All photos/videos will be published in a special section of the instructor's web site.

EXAMPLES

- ***Dye Droplets at an Oil-Water Interface***
  This image shows the portion of a glass filled with water (bottom, higher density) and coconut oil (top, lower density), and the droplets of food dye that rest on the interface between the oil and the water. It illustrates the effects of surface tension, both at the oil-water interface and at the surface of the droplets. The droplets are supported by the surface tension at the oil-water interface (they are on the oil side of the interface and thus they will not mix with the water just yet). Interfacial tension at the droplet surfaces means that they take on a spherical shape that minimizes their surface area. When the droplets diffuse through the interface and enter the water (with which they are miscible), they burst. Just below the oil interface, the different colors have not diffused into each other yet, but they have on the bottom of the water layer (as indicated by the darker color).

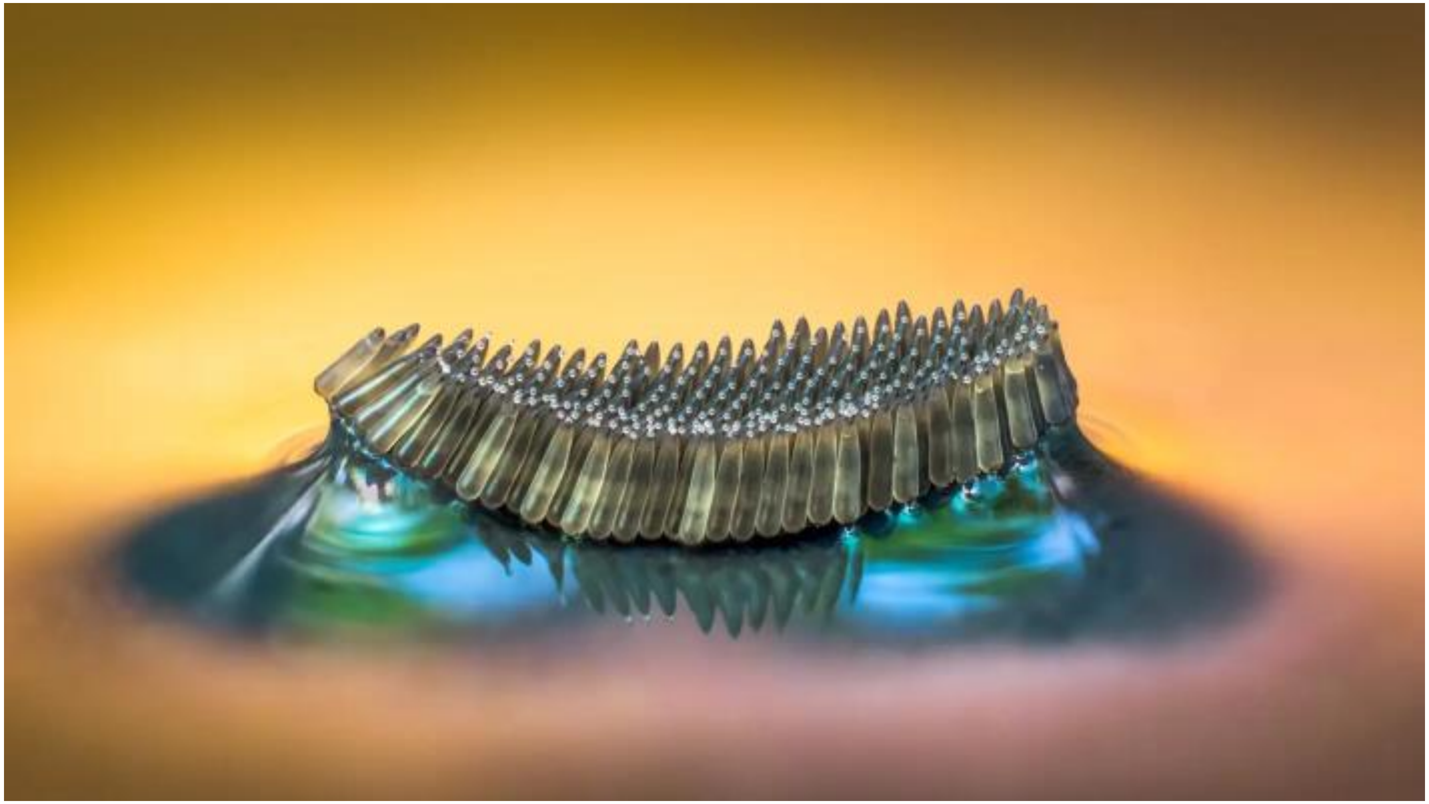
1st prize MIT photo contest 2014

EXAMPLES



Mocha Diffusion: the art of spreading miscible liquids
Tabitha C. Watson, Justin C. Burton – Department of Physics, Emory University
Ammonia dye solution on sodium alginate
Ammonia on ammonia-dye-covered corn syrup
Vinegar dye solution on xanthan gum
Propylene glycol dye solution on sodium alginate
0.3s after contact
1s after contact
1.6s after contact
2.2s after contact
2.9s after contact
McCormick food coloring on sodium alginate
Ammonia dye solution on corn syrup
Isopropanol dye solution on white acrylic paint
Propylene glycol dye solution with citric acid on sodium alginate
Dye solutions deposited on miscible viscous sub-fluids produce radial, fern-like patterns known as mocha diffusion. There are many different ways to design mocha diffusion art, but Marangoni forces and a sub-fluid viscosity that rapidly changes with water content are key ingredients.

EXAMPLES



EXAMPLES

- ***Smoke Ring***
  Smoke rings are possible through the use of toroidal vortices. A toroidal vortex occurs when a fast-moving parcel of fluid is injected into a stationary fluid. Different parameters, such as temperature, relative speed, and size of the moving fluid all affect the “crispness” of a smoke ring. Normally, a vortex is a parcel of fluid spinning around a linear axis, like a tornado or hurricane. In a toroidal vortex, the axis is still there, but it loops and closes on itself so that the vortex forms a donut shape. Thus the spinning air traps the smoke inside the vortex, forming a barrier with the surrounding, stationary fluid. This spinning flow decreases the friction between this parcel of air and the stationary air around it. Thus the ring can travel for long distances and remain intact, while other smoke trails blown out with it dissipate.

2nd prize MIT photo contest 2014

EXAMPLES

https://youtu.be/yjgACB7urOo?feature=shared

https://www.youtube.com/watch?v=oGGRxE2ijl0

https://www.youtube.com/watch?v=7wjFNl_FAnI&t=17

https://www.youtube.com/watch?v=_z099yZzQik

EXAMPLES

EXAMPLES

1st prize UWA photo contest 2013
Paint on a speaker

2nd prize UWA photo contest 2013
Dye flowing into a syphon

3rd prize UWA photo contest 2013
Water balloon to the face

UNIGE-ME FLUID PHOTO/VIDEO COMPETITION

UNIGE-ME FLUID PHOTO/VIDEO COMPETITION

Anno accademico 2014-2015   Anno accademico 2015-2016   Anno accademico 2016-2017   Anno accademico 2017-2018

To home page

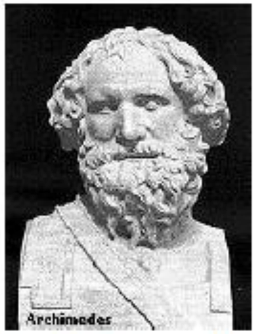
http://www.dicat.unige.it/bottaro/photovideo.html

EXAMPLES (UNIGE-ME FLUID PHOTO/VIDEO COMPETITION 2016/17)

Motivation for Studying Fluid Mechanics

- Fluid Mechanics is present almost everywhere
  - Aerodynamics
  - Bioengineering and biological systems
  - Combustion
  - Energy generation
  - Geology
  - Hydraulics and Hydrology
  - Hydrodynamics
  - Meteorology
  - Ocean and Coastal Engineering
  - Water Resources
  - …numerous other examples…
- Fluid Mechanics is beautiful

Some *Faces* in Fluid Mechanics



Archimedes

Da Vinci

Newton

Leibniz

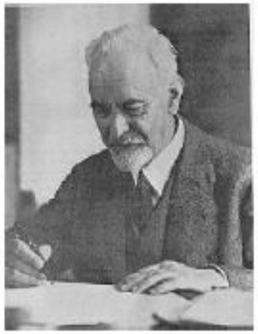
Euler

Bernoulli

Navier

Stokes

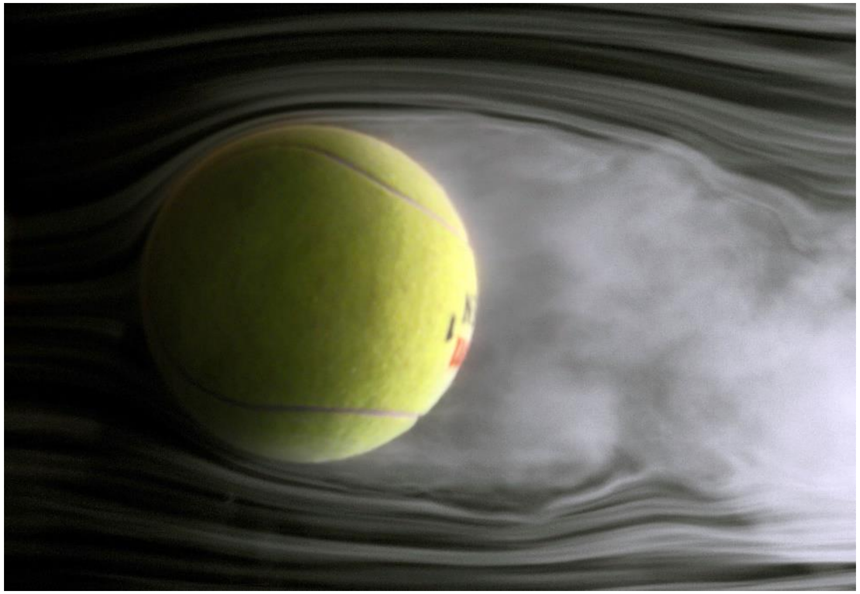
Reynolds

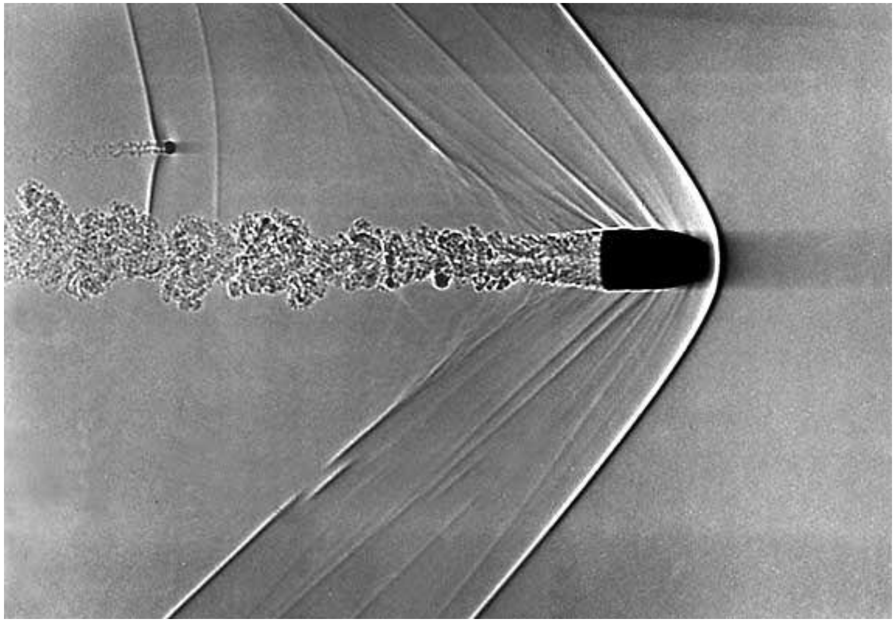


Prandtl

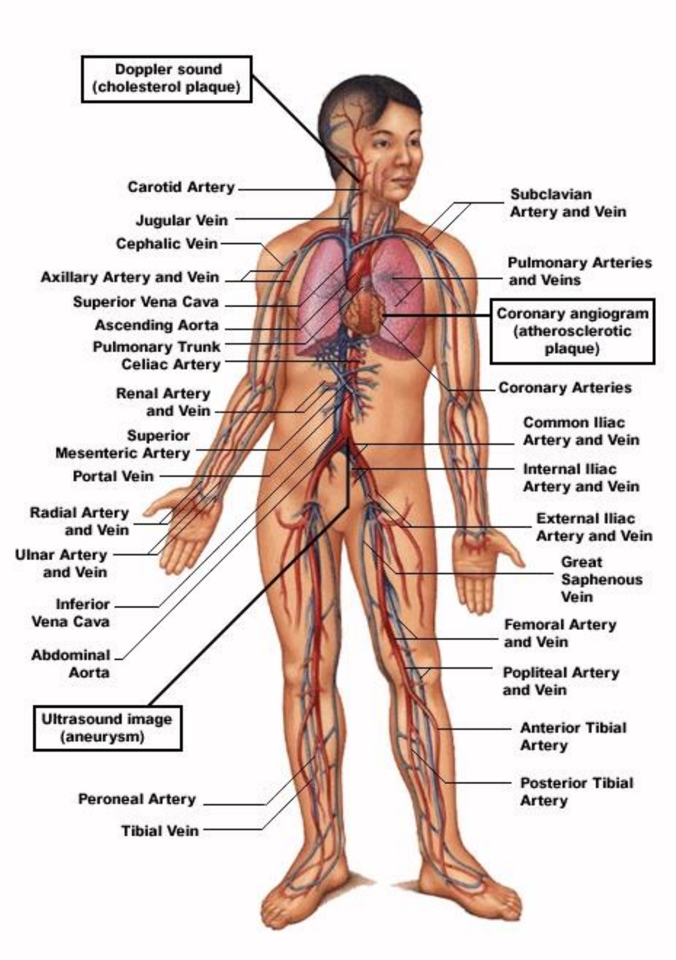
Aerodynamics

Aerodynamics





Bioengineering



Energy generation

Geology

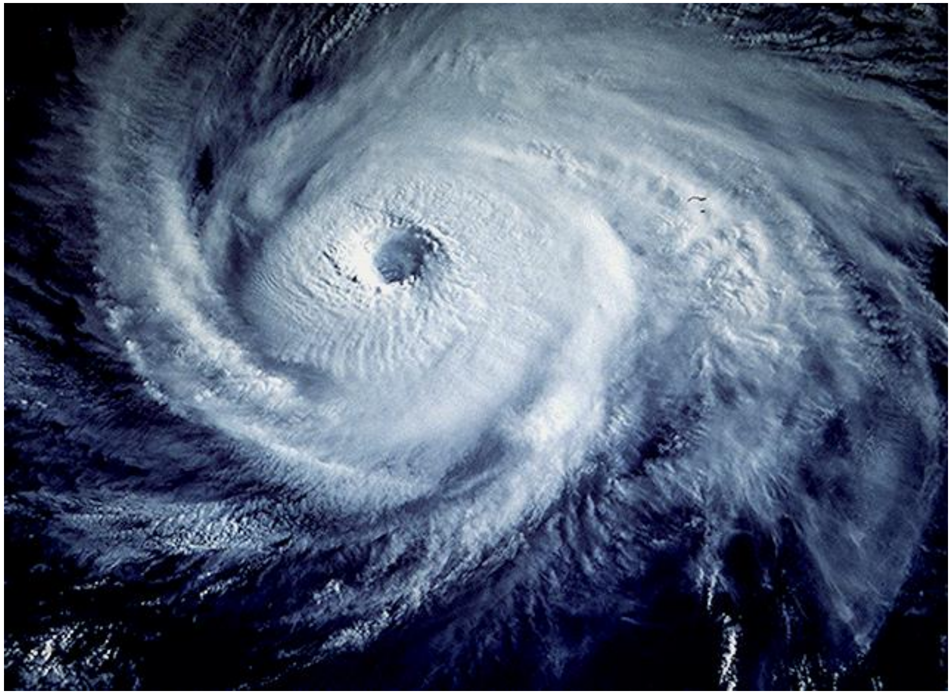
River Hydraulics

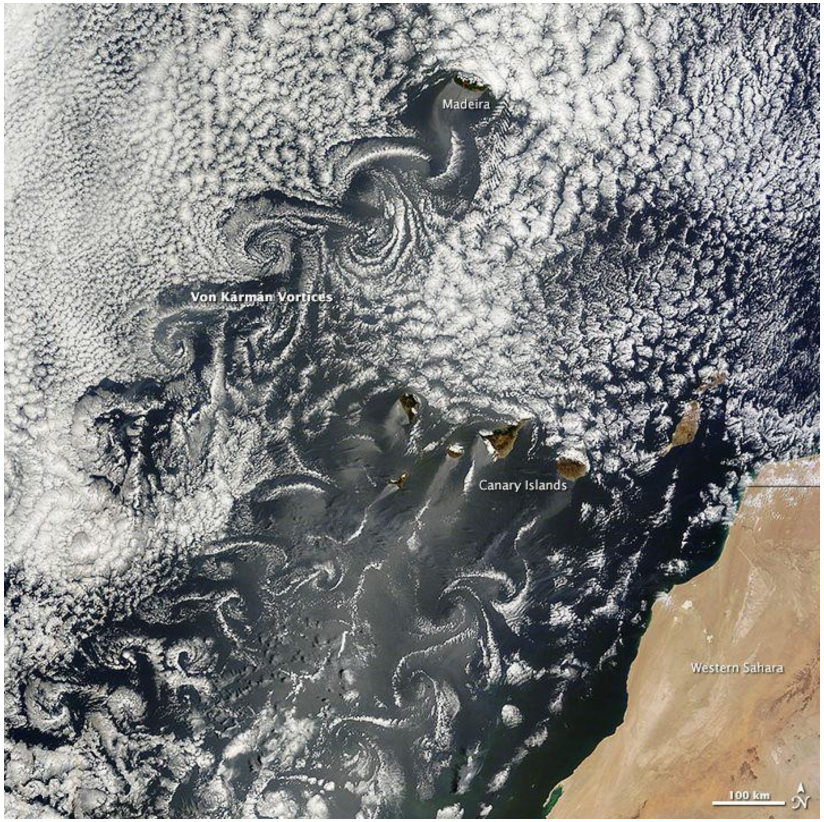
Hydraulic Structures

MOdulo **S**perimentale **E**lettromeccanico

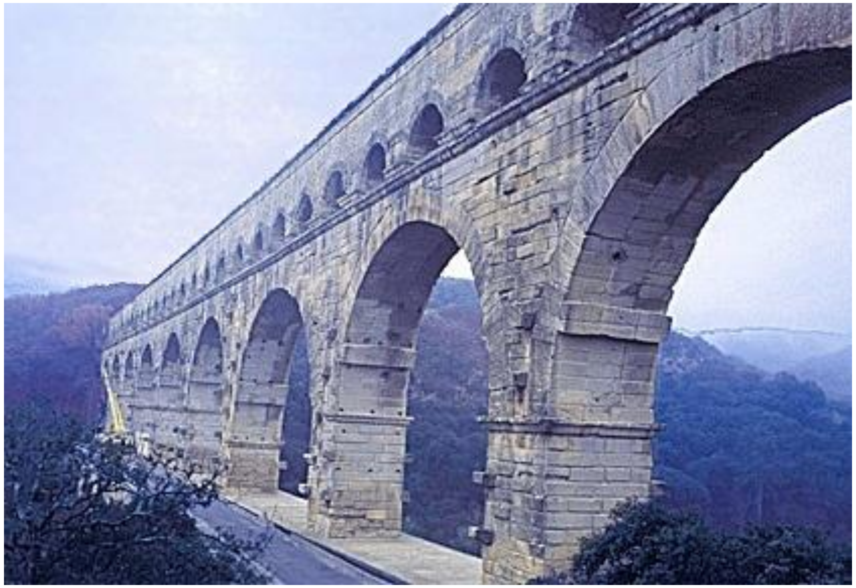
Hydrodynamics

Meteorology





Water Resources



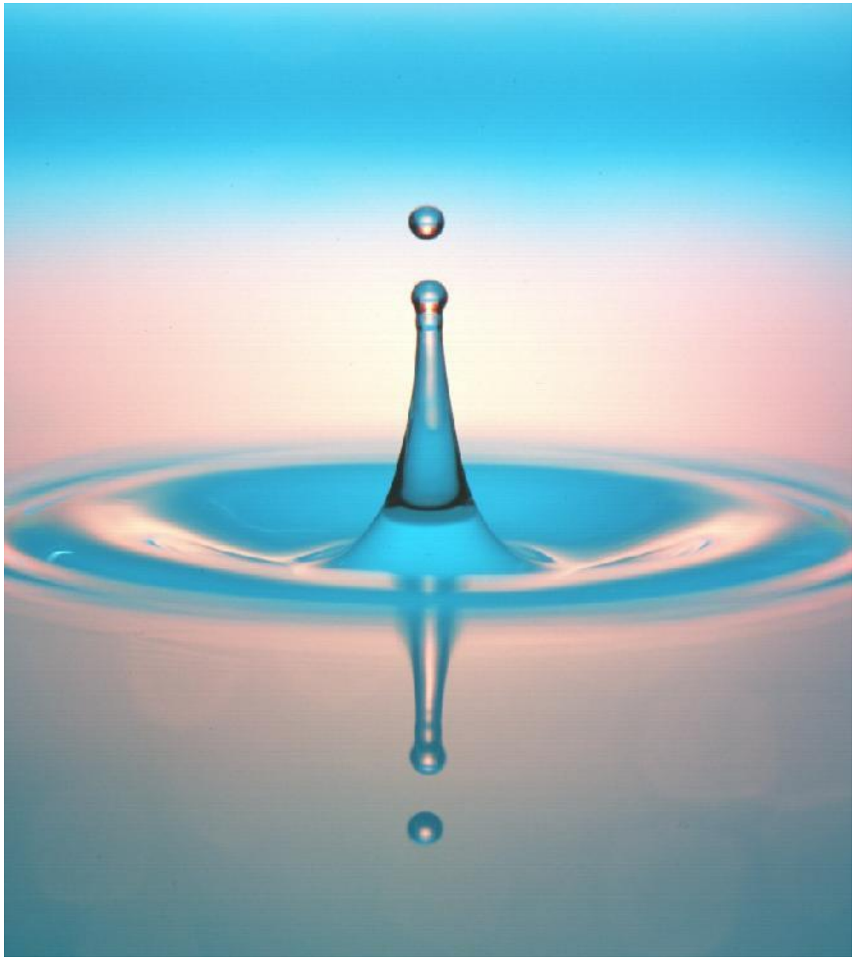
Flows of unusual materials: *Rheology*

- Foods
  - Emulsions (mayonaisse, ice cream)
  - Foams (ice cream, whipped cream)
  - Suspensions (mustard, chocolate)
  - Gels (cheese)
- Biofluids
  - Suspension (blood)
  - Gel (mucin)
  - Solutions (spittle)
- Personal Care Products
  - Suspensions (nail polish, face scrubs)
  - Solutions/Gels (shampoos, conditioners)
  - Foams (shaving cream)
- Electronic and Optical Materials
  - Liquid Crystals (Monitor displays)
  - Melts (soldering paste)
- Pharmaceuticals
  - Gels (creams, particle precursors)
  - Emulsions (creams)
  - Aerosols (nasal sprays)
- Polymers

Flows of unusual materials: *Rheology*

Die swell

Fluid Mechanics is Beautiful



Tsunamis

- Tsunami: Japanese for "Harbour Wave"
- Created by earthquakes, land slides, volcanoes, asteroids/meteors
- Pose infrequent but high risk for coastal regions.

"La grande onda presso la costa di Kanagawa", di Katsushika Hokusai, circa 1832

Tsunamis

- La Palma Mega-Tsunami = geologic time bomb? Cumbre Vieja volcano eruption could cause western half of La Palma (Canary islands) to collapse into the Atlantic and send a 100 m tsunami crashing into Eastern coast of U.S.

Methods for Solving Fluid Dynamics Problems

- *Analytical Fluid Dynamics (AFD)* Mathematical analysis of governing equations, including exact and approximate solutions. This is the primary focus of this course
- *Computational Fluid Dynamics (CFD)* Numerical solution of the governing equations
- *Experimental Fluid Dynamics (EFD)* Observation and data acquisition.

Analytical Fluid Dynamics

How fast do tsunamis travel in the deep ocean?

Incompressible Navier-Stokes equations

$$\frac{\partial \mathbf{U}}{\partial t} + (\mathbf{U} \cdot \nabla)\,\mathbf{U} = \frac{1}{\rho}\nabla p + \nu \nabla^2 \mathbf{U}$$

Linearized wave equation for inviscid, irrotational flow

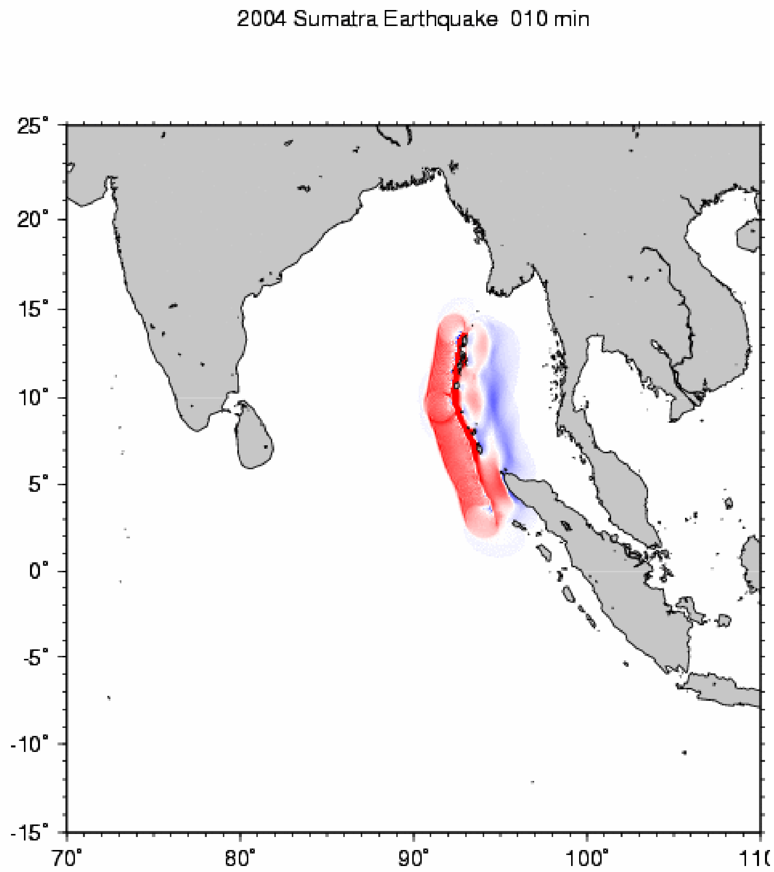
$$\nabla^2 \phi = 0, \mathbf{U} = \nabla \phi$$
$$\frac{\partial \phi}{\partial z} = 0 \text{ on } z = -h$$
$$\frac{\partial^2 \phi}{\partial t^2} = -g\frac{\partial \phi}{\partial z} \text{ on } z = 0$$

Shallow-water approximation, $\lambda/h >> 1$ (also $kh << 1$)

$$c = \sqrt{\frac{g}{k}\tanh kh} \Longrightarrow c = \sqrt{gh}$$

For $g = 9.8\ m/s^2$ and $h = 3000\ m$, $c = 171\ m/s = 617\ km/h$

Computational Fluid Dynamics



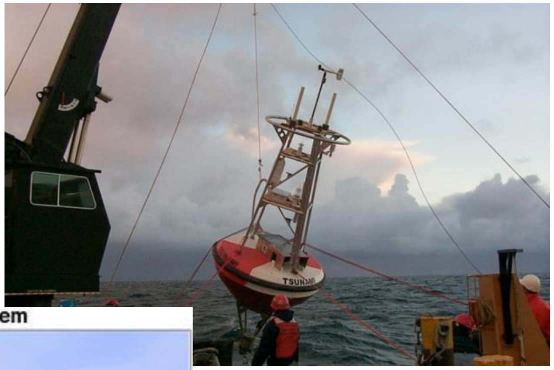
Animation by Vasily V. Titov, Tsunami Inundation Mapping Efforts, NOAA/PMEL

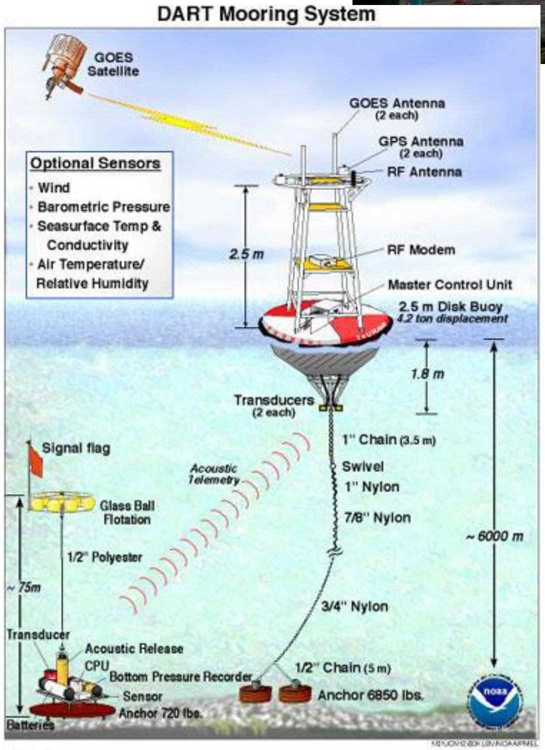
- In comparison to analytical methods, which are good for providing solutions for simple geometries or behavior for limiting conditions (such as linearized shallow water waves), CFD provides a tool for solving problems with nonlinear physics and complex geometry.

Experimental Fluid Dynamics

- Oregon State University Wave Research Laboratory
- Model-scale experimental facilities
  - Tsunami Wave Basin
  - Large Wave Flume
- Dimensional analysis is very important in designing a model experiment which represents physics of actual problem

Experimental Fluid Dynamics



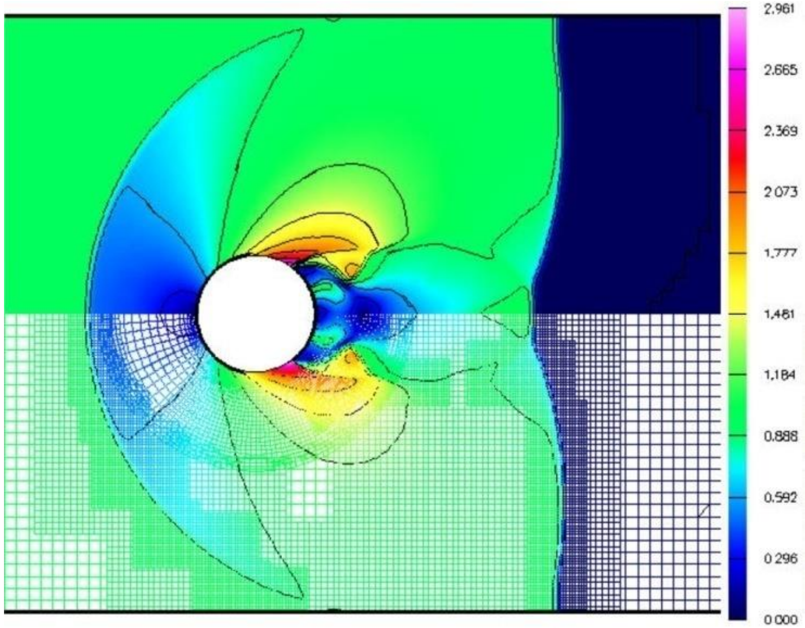


Courtesy of PMEL

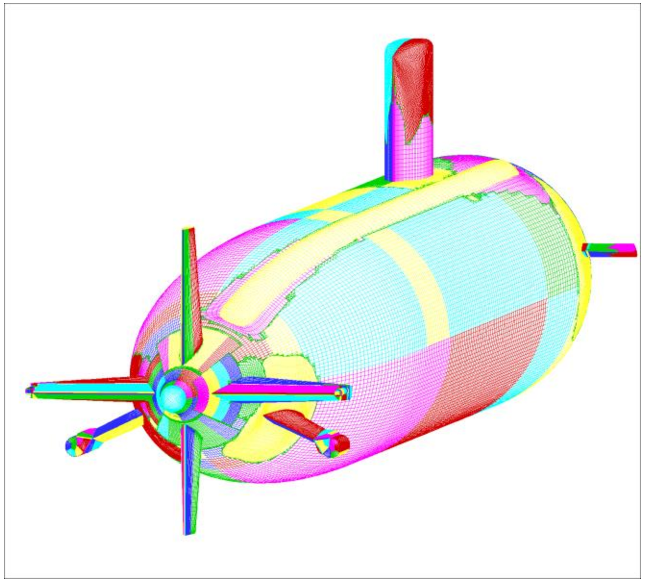
- Experiments are sometimes conducted in the field or at full scale
- For tsunamis, data acquisition is used for warning
- DART: Deep-ocean Assessment and Reporting of Tsunamis

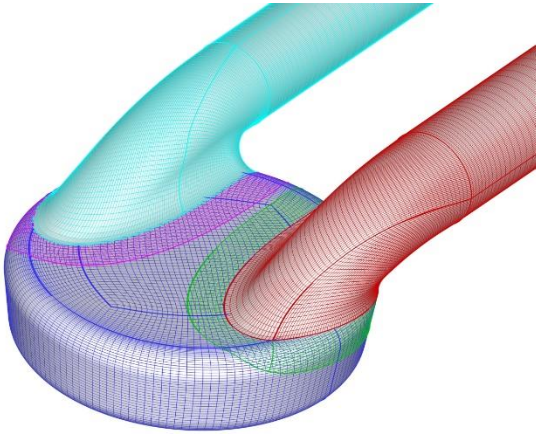
  (U.S. National Tsunami Hazard Mitigation Program)
- Primary sensor: Bourdon tube for measuring hydrostatic pressure

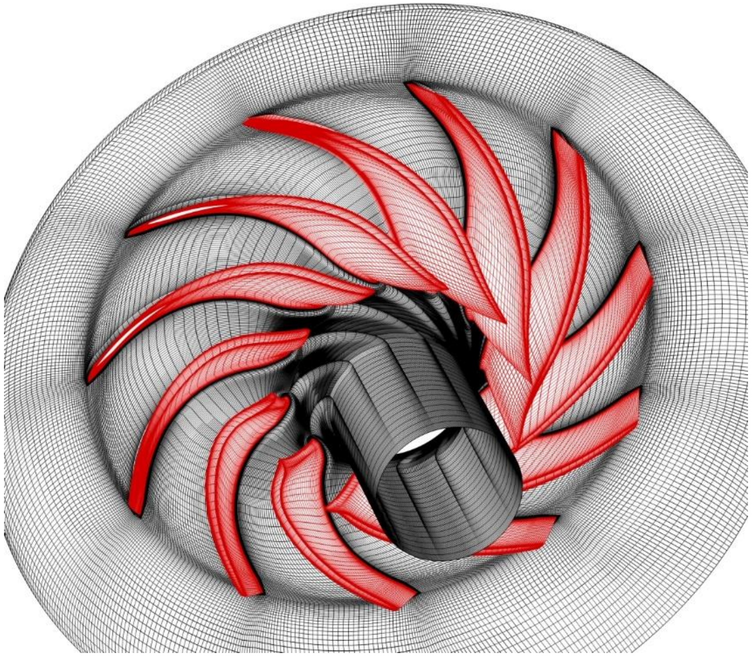
THE FLUID DYNAMICS GROUP AT DICCA

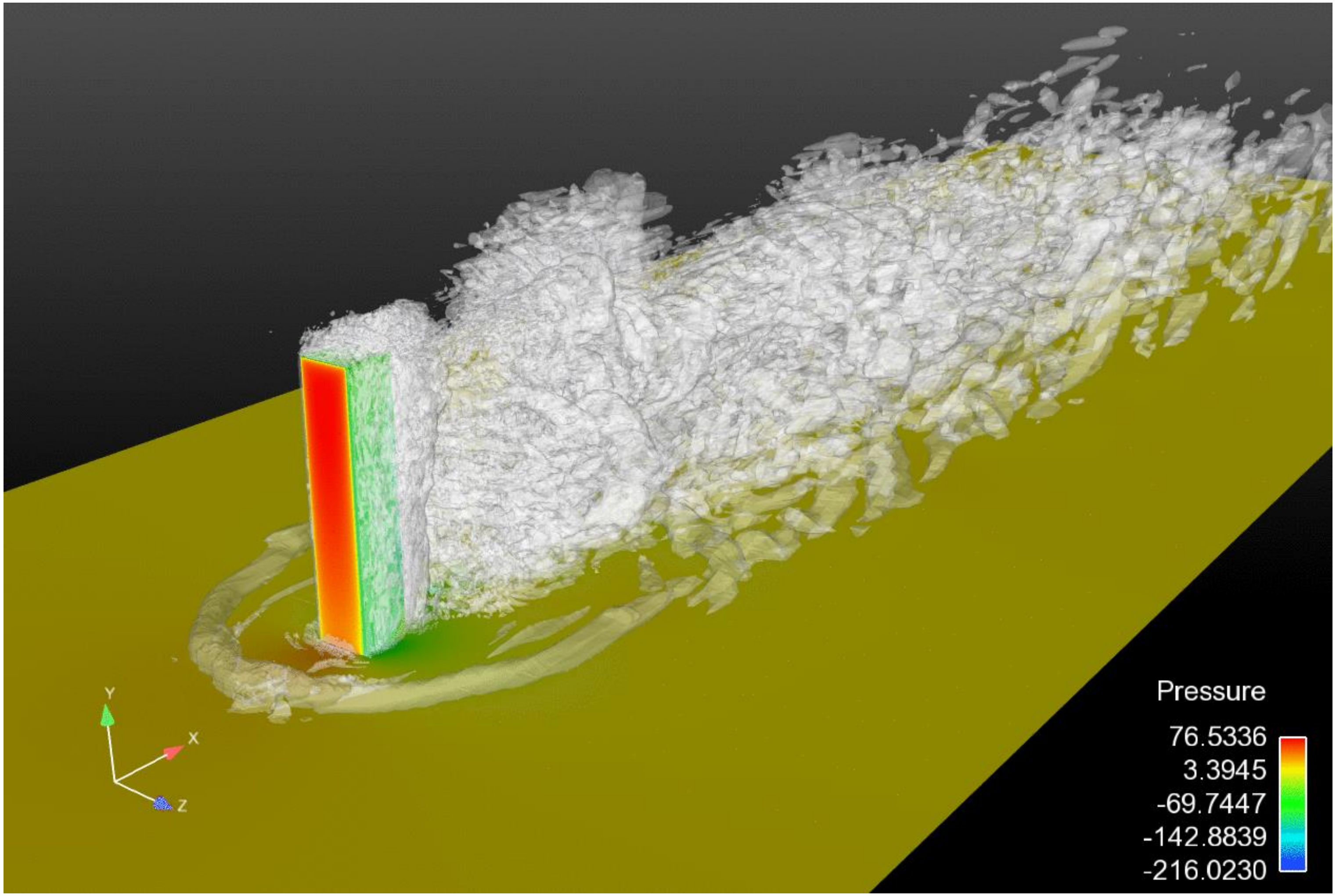


Dipartimento di Ingegneria Civile, Chimica e Ambientale, Scuola Politecnica, Università degli Studi di Genova.





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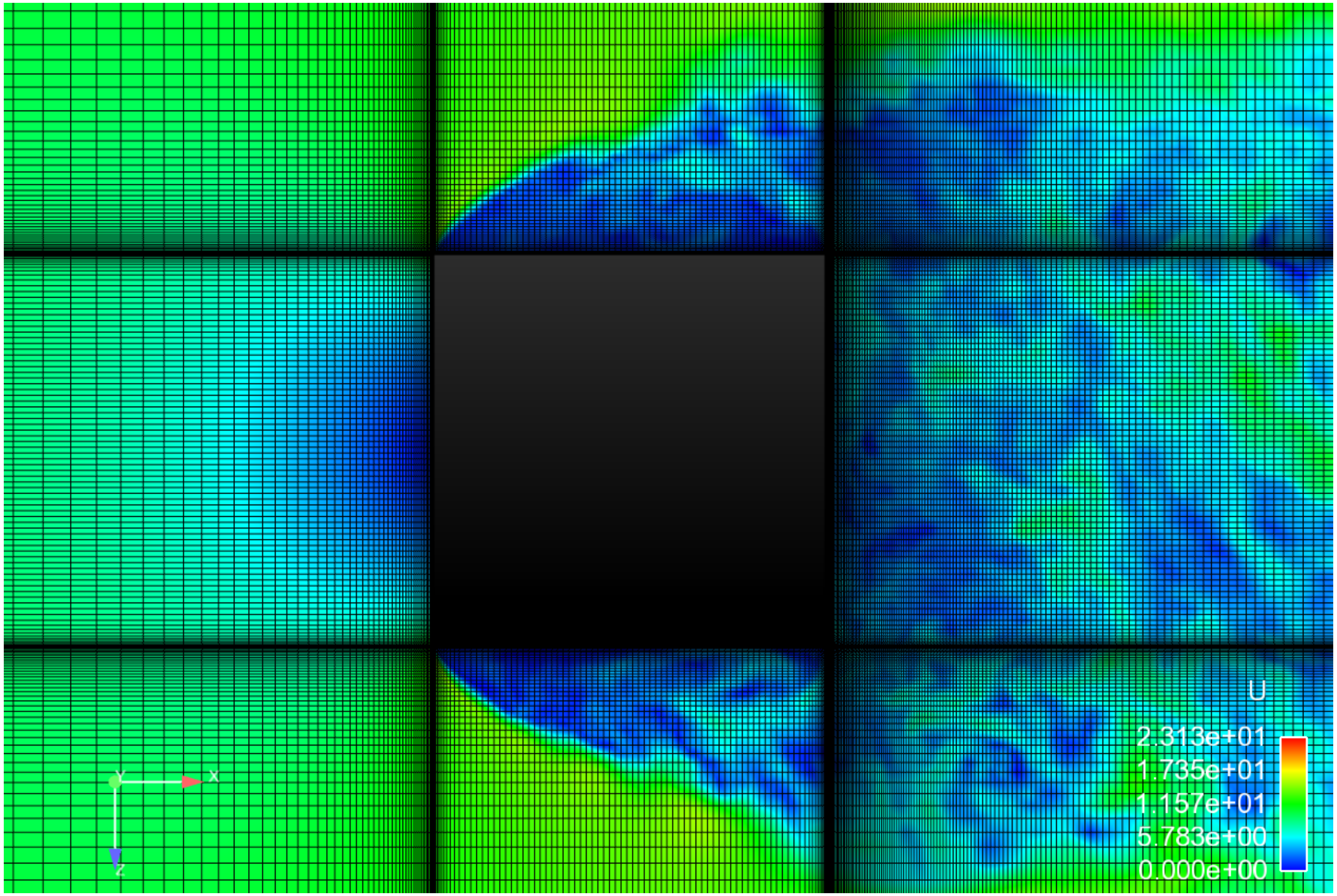
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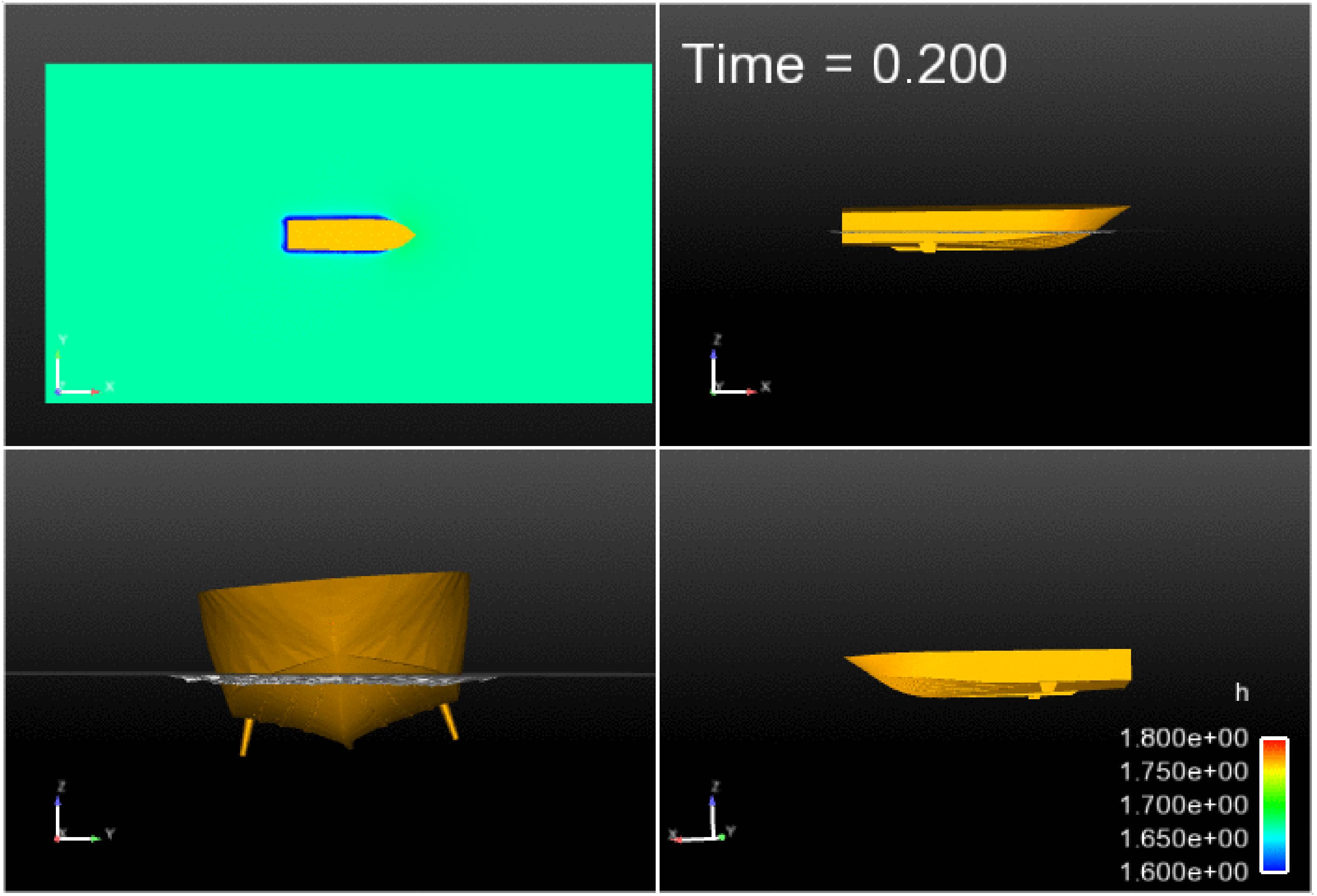
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1.650e+00
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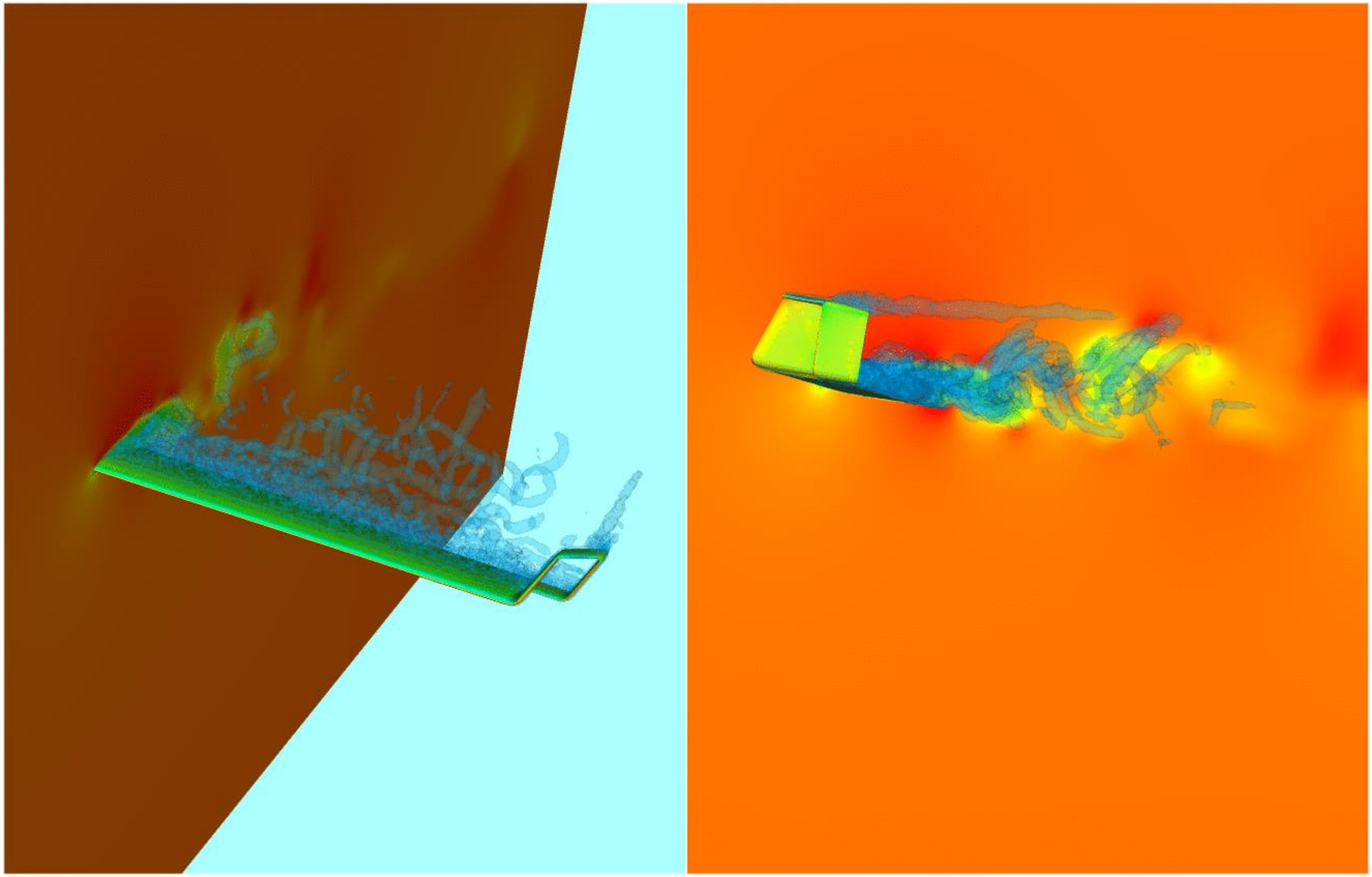
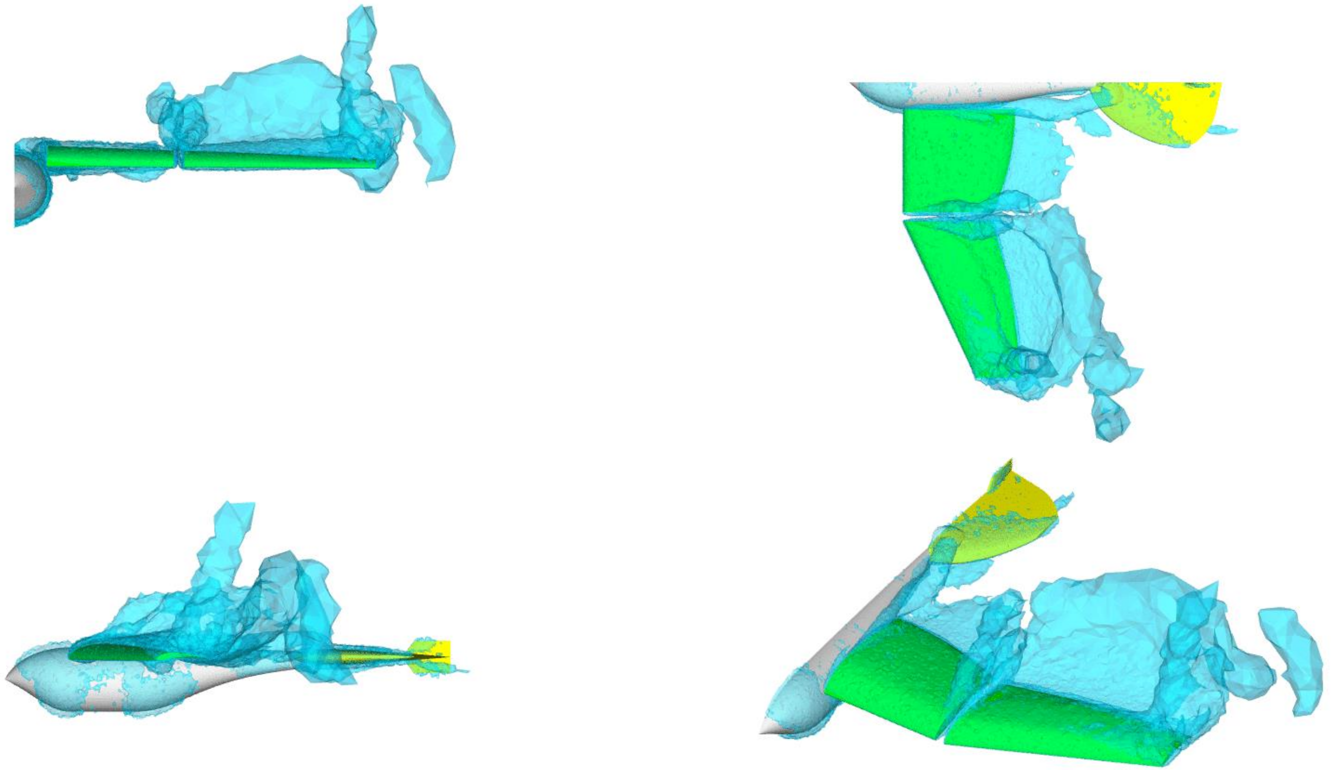
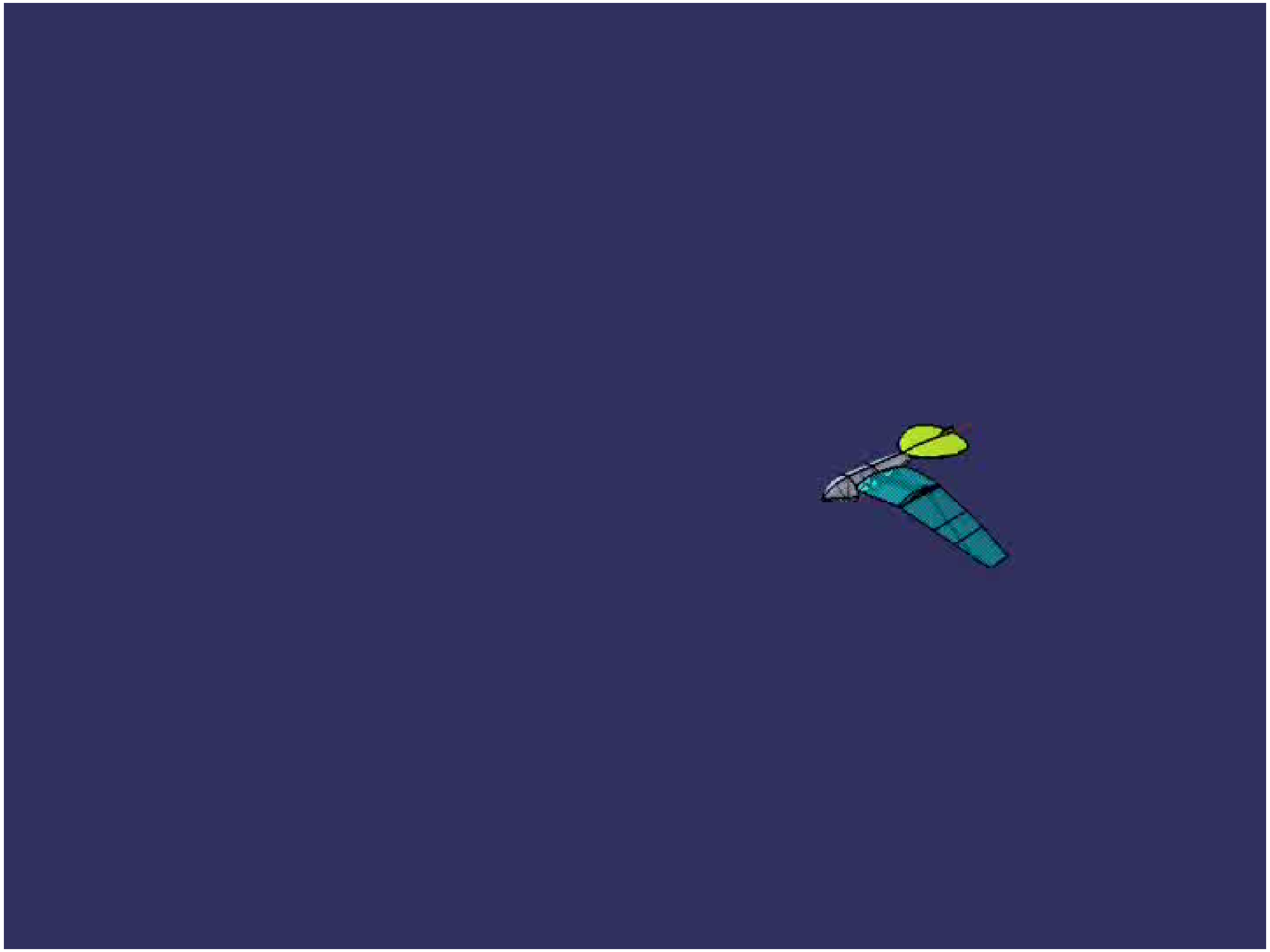


project Ornithopter

July 8, 2006





Contents of the Fluid Mechanics course

1. Introductions and basic concepts
2. Properties of fluids
3. Pressure and fluid statics
4. Fluid kinematics
5. Mass, Bernoulli and energy equation
6. Momentum analysis of flow systems

7. Dimensional analysis and π theorem
8. Internal flows and Moody chart … (TECH. PHYSICS ?!)
9. Differential analysis of fluid flows
10. Approximate solutions of the Navier-Stokes equations
11. External flows: drag and lift