Thermal and Fluids Curriculum Laboratory Integration

The integrated Thermal Fluids curriculum

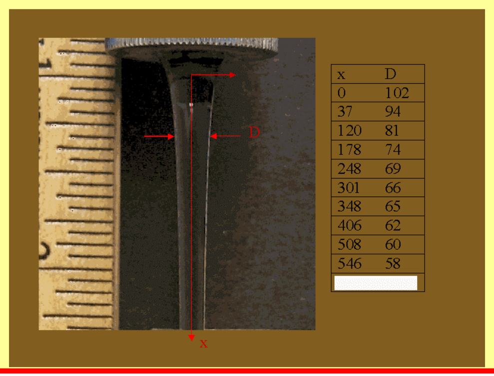
Course Description

- Integrate traditional subjects of Thermodynamics, Heat Transfer and Fluid Mechanics into one coherent two-semester course sequence
- Place emphasis on the connection between different interdisciplinary subjects (see table A)
- Conduct three one-hour lectures plus one three-hour workshop session
- Use real-world case studies throughout the class (see table B)

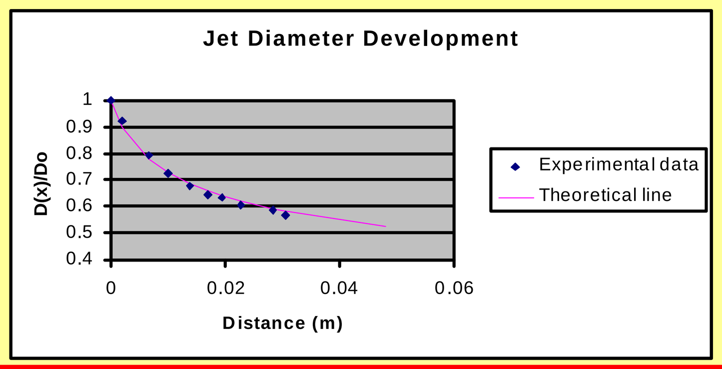
An Active Example

A classical example problem of water flow from a downward-pointing pipe is reproduced using a digital camera as shown below. Students can digitize the image and determine the diameter of the water stream as a function of the distance below the pipe. They can then compare their theoretical calculation, using the Bernoulli's and the mass conservation equations, with the experimental results (shown below). This type of active examples can inject life into many otherwise uninspiring examples.

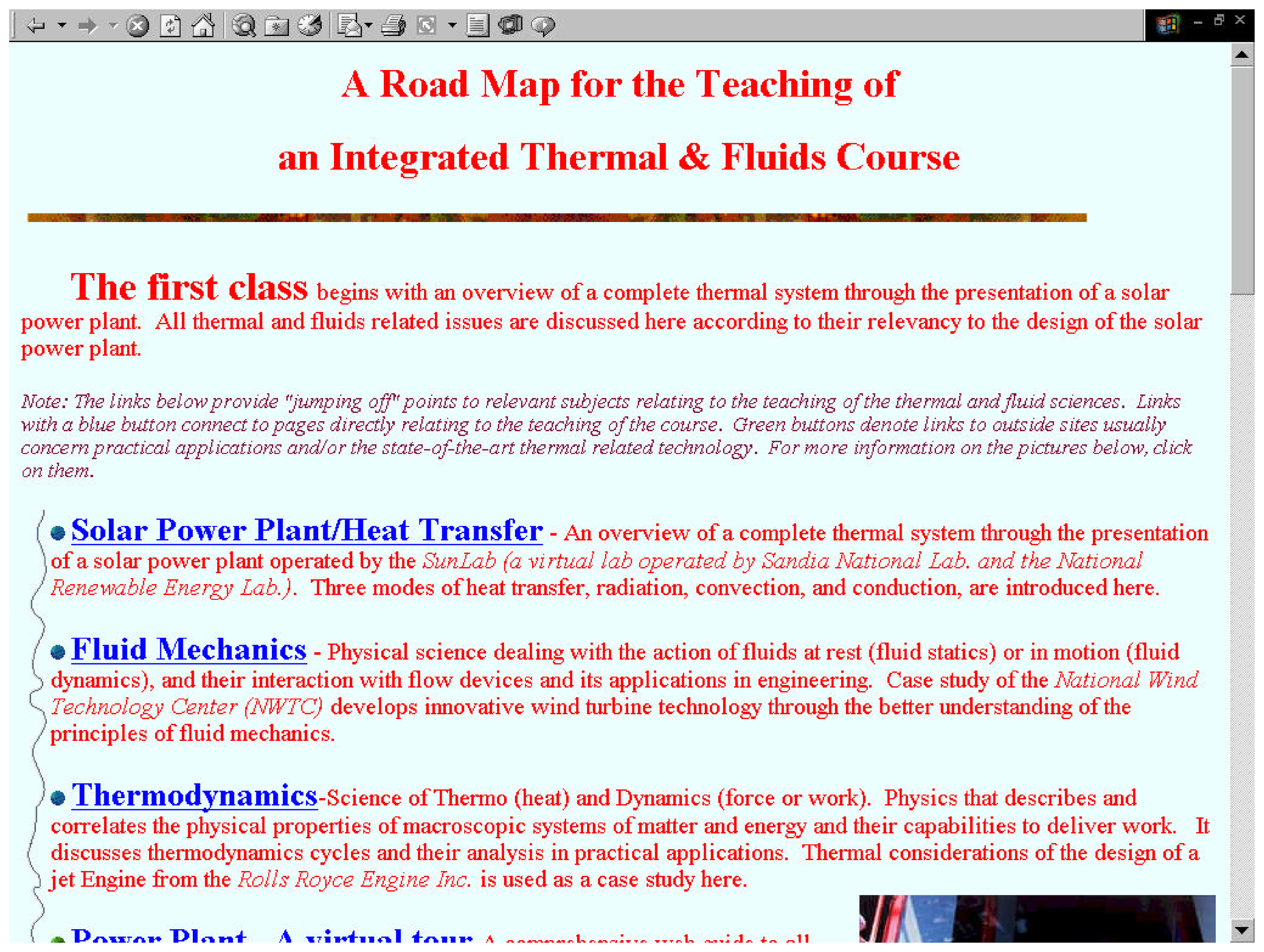
Digital image of the jet



Experimental & theoretical data comparison



Sample Road Map



A Road Map for the Teaching of

an Integrated Thermal & Fluids Course

The first class begins with an overview of a complete thermal system through the presentation of a solar power plant. All thermal and fluids related issues are discussed here according to their relevancy to the design of the solar power plant.

Note: The links below provide "jumping off" points to relevant subjects relating to the teaching of the thermal and fluid sciences. Links with a blue button connect to pages directly relating to the teaching of the course. Green buttons denote links to outside sites usually concern practical applications and/or the state-of-the-art thermal related technology. For more information on the pictures below, click on them.

- **Solar Power Plant/Heat Transfer** - An overview of a complete thermal system through the presentation of a solar power plant operated by the *SunLab (a virtual lab operated by Sandia National Lab. and the National Renewable Energy Lab.)*. Three modes of heat transfer, radiation, convection, and conduction, are introduced here.
- **Fluid Mechanics** - Physical science dealing with the action of fluids at rest (fluid statics) or in motion (fluid dynamics), and their interaction with flow devices and its applications in engineering. Case study of the *National Wind Technology Center (NWTC)* develops innovative wind turbine technology through the better understanding of the principles of fluid mechanics.
- **Thermodynamics**-Science of Thermo (heat) and Dynamics (force or work). Physics that describes and correlates the physical properties of macroscopic systems of matter and energy and their capabilities to deliver work. It discusses thermodynamics cycles and their analysis in practical applications. Thermal considerations of the design of a jet Engine from the *Rolls Royce Engine Inc.* is used as a case study here.

Table A. Sample Integrated Concepts

SAMPLE CONCEPTS FOR INTEGRATION	THERMODYNAMICS	HEAT TRANSFER	FLUID MECHANICS
Conservation Principles	1st Law Mass Conservation	Heat Diffusion Equation	"Extended" Bernoulli's Equation Continuity Equation
Entropy	2nd Law Thermal Efficiency	Heat Transfer	Viscous Dissipation
Internal Flows	Open Flow Process	Forced Convection	Pipe Flow Laminar/Turbulence
External Flows		Forced Convection Thermal Boundary Layer	Boundary Layer Flow Separation
Compressible Flows	Ideal Gas Law Isentropic Process		Mass, Energy and Momentum Conservation
General	Pressure Specific Volume Temperature Work Energy	Temperature Gradient Thermal energy Thermal Diffusion (Thermal diffusivity)	Hydrostatic Pressure Density Flow work Mechanical Energy Momentum Diffusion (Viscosity)

Integration

Web-Based Delivery/Supplements

- Comprehensive course web pages were developed to provide step-by-step on-line guidance
  - Daily lecture notes, weekly workshop assignments and other class supplementary materials **(www.eng.fsu.edu/~shih/eml3015 & www.eng.fsu.edu/~shih/eml3016)**
- A *ROAD MAP* section (see sample road map page)
  - Guides students through different topics
  - Provides a smooth transition
  - Includes extensive hyperlinks to relevant subjects for beyond-textbook experience (see **A Road Map for the Teaching of an Integrated Thermal & Fluids Course** in the SUCCEED's Greatest Bits, Vol. 3 CD, 2000)
- Weekly three-hour on-line workshop:
  - Active examples (see example to the left) and hands-on demonstrations: students model and solve thermal problems following on-line presentations of experiments/examples

Textbooks:
Thermodynamics & Heat Transfer: *"Introduction to Thermodynamics and Heat Transfer"*, by Yunus Cengel, McGraw-Hill
Fluid Mechanics: *"Introduction to Fluid Mechanics"*, by Fox & McDonald, Wiley

Table B. Sample Case Studies

CASE STUDIES	THERMODYNAMICS	HEAT TRANSFER	FLUID MECHNICS
Solar Power Plant	Stirling Cycle Thermal Efficiency	Radiation Conduction Convection	Pipe Flow Analysis
Jet Engines	Brayton Cycle Ideal Gas Law	Turbine Blade Film Cooling	Jet Propulsion Momentum Balance Thrust Vectoring
Nuclear Power Plant	Rankine Cycle Superheat, Reheat, Regeneration	Heat Exchanger Condenser	Pipe Flow Analysis Turbomachinery
Internal Combustion Engine	Otto & Diesel Cycles		
Enhanced Heat Transfer (Electronic cooling)		Extended Surfaces Fin	
Thermal Spray Process		Transient Heat Transfer Semi-Infinite Heat Transfer	Jet Flow Mixing Aerodynamic Drag
Hydropower Plant			Hydrostatic Pressure Forces on Submerged Surfaces
Trans-Alaska Pipeline		Heat Losses Heat Pipe Technology	Pipe Flow Major/Minor Losses
MEMS/Thermal Bubble Jet Printing Process		Boiling Heat Transfer Thin-Film Heat Transfer	Aerodynamic Drag Rayleigh Jet Instability

Thermal Fluids Laboratory Integration

Laboratory Course Description

- Provide "Just-In-Time" hands-on laboratory experience in Thermal/Fluids related subjects
- Provide on-line web lab manuals and interactive experiments (currently under development) for a *"Virtual Laboratory"* environment
- Emphasize the *"Seeing is Believing"* concept.
  - Develop visualization-enhanced projects: For example, see Qualitative Flow Visualization included in the SUCCEED's Greatest Bits, Vol. 2 CD, 1999
- Implement *"Learning through Teaching"* strategy.
  - Students present laboratory demonstrations to fellow students to gain valuable higher-level learning experience (currently under development)

Laboratory Organization

- Reinforce and enhance students' understanding of the fundamentals of fluid mechanics and heat transfer learned in Thermal Fluids I & II through hands-on laboratory experience
- Weekly schedule includes two one-hour lectures and one three-hour laboratory. Students are divided in groups of four students/group and each group performs one experiment/week.
- Students conduct a total of ten experiments (eight hands-on laboratoies and two demonstrations)
  - www.eng.fsu.edu/~alvi/eml4304L/webpage

Program Assessment

So far, no systematic assessment has been done on the effectiveness of our new teaching format. However, we can use the students' evaluation surveys to make a qualitative comparison. Only Professor Shih's surveys were used since he was responsible for teaching the integrated courses. The evaluation is based on a scale from excellent (being 1), very good, good, fair, to poor (being 5). It can be clearly seen that there is a significant improvement both in the categories of the overall assessment of instructor (from 2.14 to 1.65) and the facilitation of learning (from 2.36 to 1.79). It is somewhat surprising that there is no change in the category of stimulation of interest. However, it might reflect a general trend that students, on average, have become less enthusiastic as compared to their fellow students who graduated five years or earlier. (Note: all traditional thermal classes were taught by Shih before 1994, while the integrated curriculum began fall 1988). The improvement in the first two categories seems to suggest that the integrated thermal fluids curriculum is promising.