Curriculum Reform of the Mechanical Engineering Program at the City College of New York

PI: F. Delale, CoPIs: G. Benenson, L. Jiji, J. Hammonds

Supported by NSF and in collaboration with ASME

OBJECTIVES

- ➢ Incorporation of Emerging Technologies into the Mechanical Engineering Curriculum
- ➢ Introduction of New Teaching Strategies Focused on Student Learning
- ➢ Recruitment and Retention Efforts to Increase Students Majoring in Mechanical Engineering, Especially Underrepresented Minorities and Women

INCORPORATION OF EMERGING TECHNOLOGIES INTO THE ME CURRICULUM

- ➢ MEMS/NEMS
- ➢ Advanced Materials
- ➢ Computer Aided Engineering
- ➢ Intelligent Systems/Electronics
- ➢ Biotechnology
- ➢ Nanotechnology
- ➢ Nontraditional Energy

INCORPORATION OF NEW TEACHING STRATEGIES

- ➢ Cooperative Learning
- ➢ Project-based Learning
- ➢ Research Methods
- ➢ Laboratory Experience
- ➢ Independent Learning

RECRUITMENT AND RETENTION

- ➢ RECRUITMENT
  - -- The Freshmen / High School Design Contest
  - -- The ASME, SAE and AIAA Design Contests
  - -- Reverse Engineering Workshop
- ➢ RETENTION
  - -- Early Exposure to Engineering
  - -- Early Intervention with Marginal Students
  - -- Creating a Receptive Environment for Women Students

ELIMINATION AND ADDITION OF COURSES NEW SCIENCE REQUIREMENTS

- ➢ New course: *Micro/Nano Materials and Manufacturing*
- ➢ Combine: Thermodynamics II, Energy Systems Design, To one New course: Thermal Systems Design and Analysis
- ➢ Establish new Energy System Laboratory
- ➢ Restrict 2nd Science Elective to: Human Physiology, Organic Chemistry or Modern Physics

COLLABORATION WITH ASME

- ➢ Incorporation of ***ASME Professional Practice Curriculum Modules*** into the ME curriculum
- ➢ Effective Teaching Workshop
- ➢ Industry Advisory Board
- ➢ Dissemination

INCORPORATION OF EMERGING TECHNOLOGIES

New Micro/Nano Technology Course

ME 46300: Micro/Nano Technology: Mechanics, Materials, and Manufacturing

The aim of this course is to introduce students with diverse technical interests to the emerging area of micro and nano phenomena in science and engineering. Micro-Electrical Mechanical Systems (MEMS) and Nanotechnology continue to revolutionize research in the engineering and science communities requiring newcomers to familiarize themselves with these fundamental principles. This course will address synthesis and manufacturing techniques of micro/nano devices, relevant mechanics concepts (such as fracture and contact mechanics, elasticity), material property determination at small scales (e.g. size-scale strength effects), and engineering difficulties with manipulation and control of materials and phenomena on scales less than 1000 times the width of a human hair. The course will be centered upon a series of investigational exercises including microfludics experiments, electro-mechanical testing of microdevices, transport and deposition of macromolecules (e.g. DNA, proteins), nanolithography, and manipulation of carbon nanotubes. Course material will also briefly discuss the evolution of select micro/nano innovations and their impact and applications in applied sciences, medicine, space development, policy, and the environment.

EXAMPLE OF COURSE MODIFICATION: HEAT TRANSFER

MODIFICATION CRITERIA

(1) Preserve Fundamentals of Conduction, Convection and Radiation
(2) No Additional Math or Physics Requirements

NEW TOPICS ADDED

- ➢ Conduction with phase change:
- ➢ Freezing of Water (Home experiment)
- ➢ Heat transfer in living tissue
- ➢ Convection in microchannels

(1) CONDUCTION WITH PHASE CHANGE

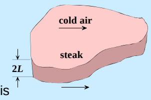
Simplified Model: Quasi-steady Approximation

Criterion: Small Stefan number: $Ste = \frac{c_{ps}(T_f - T_o)}{\mathcal{L}}$

Governing equations: $\frac{d^2T_S}{dx^2} = 0 \qquad \frac{d^2T_L}{dx^2} = 0$

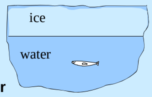
Interface energy equation: $k_s \frac{\partial T_s(x_i,t)}{\partial x} - k_L \frac{\partial T_L(x_i,t)}{\partial x} = \rho_s \mathcal{L} \frac{dx_i}{dt}$

Applications



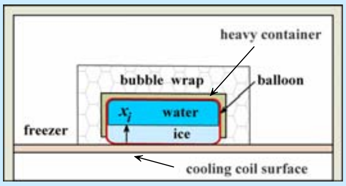
a) **Freezing of steak:**
How long does it take for stake to freeze after it is placed in a sub-freezing chamber?

b) Thawing of an apple:
How long does it take for an apple to thaw?



c) Freezing of deep lake:
How long after a sub-freezing storm will an ice layer of a specified thickness form ?

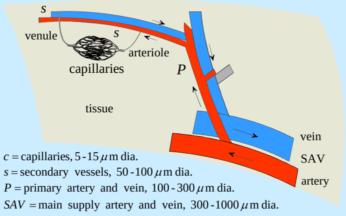
d) Home Experiment: Freezing of Water



- ➢ Fill balloon with water at fusion temperature
- ➢ Place on the cooling coil surface of freezer
- ➢ Cover all sides with insulation
- ➢ Measure frozen layer thickness after 3 hours
- ➢ Compare with theoretical prediction

(2) HEAT TRANSFR IN LIVING TISSUE

Vascular Architecture and Blood Flow

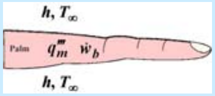


c = capillaries, 5-15 μm dia.
s = secondary vessels, 50-100 μm dia.
P = primary artery and vein, 100-300 μm dia.
SAV = main supply artery and vein, 300-1000 μm dia.

Pennes Bioheat Equation $\frac{d^2T}{dx^2} + \frac{\rho_b c_b \dot{w}_b}{k}(T_{a0} - T) + \frac{q'''_m}{k} = 0$

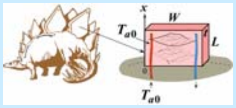
Applications

- ● **Temperature Distribution in the Palm**

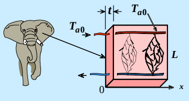


- ● **Fin Approximations in Tissue Heat Transfer**

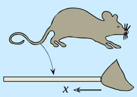
(i) The dinosaur Stegosaurus



(ii) The elephant ear



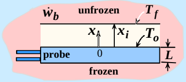
(iii) The rat tail



The fin equation: $\frac{d^2\theta}{d\xi^2} - (m+\beta)\theta + m = 0$

$$\theta = \frac{T - T_{a0}}{T_\infty - T_{a0}}, \quad \xi = \frac{x}{L}, \quad m = \frac{2h(W+t)L^2}{kWt}, \quad \beta = \frac{\dot{w}_b \rho_b c_b L^2}{k}$$

Tissue freezing: Cryosurgical probes (application of phase change):



(3) CONVECTION IN MICROCHANNELS

Knudsen number $Kn = \frac{\lambda}{D_e}$

Classification:

$Kn < 0.001$	Continuum, no-slip flow
$0.001 < Kn < 0.1$	Continuum, slip flow
$0.1 < Kn < 10$	Transition flow
$10 < 10$	Free molecular flow

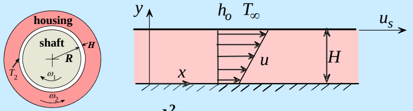
Boundary conditions

Velocity slip $u(x,0) = \lambda \frac{\partial u(x,0)}{\partial n}$

Temperature jump $T(x,0) - T_s = \frac{2\gamma}{1+\gamma} \frac{\lambda}{Pr} \frac{\partial T(x,0)}{\partial n}$

Applications:

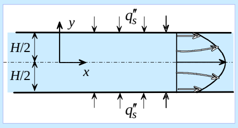
(1) Couette flow



Governing equations: $\frac{d^2u}{dy^2} = 0$

Temperature: $\frac{d^2T}{dy^2} = -\frac{\mu}{k}\left(\frac{du}{dy}\right)^2$

(2) Fully Developed Poiseuille flow: Uniform surface flux

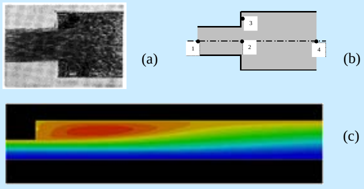


Determine:

- ● Velocity distribution
- ● Pressure distribution
- ● Mass flow rate
- ● Nusselt number

(3) Fully Developed Poiseuille flow: Uniform surface temperature

NEW TEACHING STRATEGIES (FLUID MECHANICS): Fluid Flow Visualization



a) Experimental flow visualization of flow through and expansion, from *Visualized Flow,* Japan Society of Mechanical Engineers; Pergamon Press, 1988, b) typical diagram for control volume analysis of flow through an expansion, and c) CFD visualization of flow through an expansion created FLOWLAB software

NEW TEACHING STRATEGIES: AN EXAMPLE

INCORPORATION OF HOME EXPERIMENTS INTO MECHANICS OF MATERIALS COURSE

Home Experiments: Students perform simple experiments at home using common materials and supplies to learn about concept introduced in class

Experiment 1: Elongation in Axial Loading

Suspend a ruler with two nylon fishing lines as shown in Fig. a Apply a load to the ruler at a point between the two lines and measure the elongations of the two lines. Compare your result with theoretical prediction of the elongations.

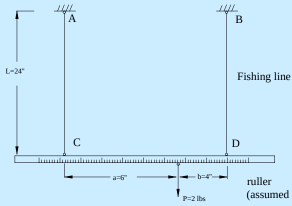


Fig a

Experiment 2: Bending Failure of Chalk

Supports a stick of chalk horizontally at both ends on two round pencils as shown in Fig. b. Load the chalk by suspending a weight at its mid-span. Increase the load until failure occurs. Use theory and data from this test to predict failure due to a load at another location. Compare with you experimental result.

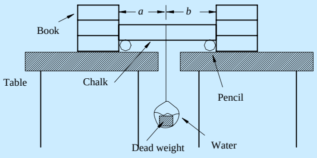


Fig b

Experiment 3: Torsion Failure of Chalk

Apply torsion to a stick of chalk by placing it vertically on a table and suspending a load with a string wrapped around the chalk as shown in Fig. c. Increase the load until failure occurs. Compare with theoretical prediction of failure load.

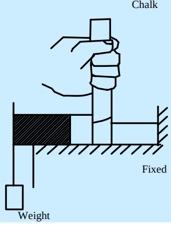


Fig c