A SURVEY ON EMERGING TECHNOLOGIES IN CHEMICAL ENGINEERING

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Edwin O. Eisen

McNeese State University

Lake Charles, Louisiana

SURVEY ON EMERGING TECHNOLOGIES

IN CHEMICAL ENGINEERING

Chemical engineering is experiencing a change. There is a sharp decrease in demand for B.S. chemical engineers by the chemical and petrochemical industries. Decreased demand for gasoline and refined petroleum products has shut down 104 refineries in the United States since 1980, leaving about 190 in operation. Unemployment in Gulf Coast cities, whose economy is strongly dependent on oil, hovers at 13%, almost twice the national average. Finally, freshman enrollment in chemical engineering has decreased by 50% between 1980 and 1984.

Traditional employers of chemical engineers have sharply reduced their recruiting. Academia must identify new areas of employment and provide appropriate training so B.S. chemical engineers can compete for these positions.

The Chemical Engineering Education Projects Committee of AIChE conducted a survey in March, 1985 on emerging technologies in chemical engineering and two other subjects. A questionnaire was sent to 169 chemical engineering departments in the United States and Canada. Seventy-six replies were received.

The purpose of the survey is to inform the academic community of existing courses, to observe trends, and to stimulate sharing of resource material in these areas among chemical engineering departments. Information was collected about courses in bioengineering, biomedical engineering, processing of microprocessor materials, advanced separation techniques, alternate energy sources, microcomputer interfacing, etc. Conventional elective courses in areas like process design, advanced unit operations and applied mathematics were excluded from consideration.

The titles of all courses named on the completed questionnaires are listed by department at the end of this paper. Anyone interested in specific courses can contact the respective department for further information.

Of the 76 replies received, 15 departments indicated they offered no courses in the emerging technologies. It is perhaps poor form to speculate on "non-replies". In this case, however, it may be appropriate to conclude that 20% of the departments have not identified which technologies will be of sufficient future importance to warrant specialized course offerings.

TABLE 1

BIOTECHNOLOGY

Courses	
Graduate	3
Senior	50
Junior	3
	56
Elective	52
Required	1

Times Taught	1980-85
Never	8
1	9
2	10
3	10
4	2
5	15

TABLE 2

MICROELECTRONIC MATERIALS

Courses	
Graduate	2
Senior	18
Junior	6
	23
Elective	21
Required	0

Times Taught	1980-85
Never	5
1	7
2	7
3	2
4	0
5	1

UNIVERSITY OF AKRON

Electrochemical Engineering	Sr/S1
Digitized Data	Jr/S2
Biochemical Engineering	Jr/S1
Synfuels	Jr/S2

UNIVERSITY OF ALBERTA

Energy Resource Development	Sr/S1
Intro. to Real-time Computer Applications	Sr/S1

ARIZONA STATE UNIVERSITY

Semiconductor Material Processing	Sr
Electronic Materials	Grad
Biomaterials	Sr

UNIVERSITY OF ARKANSAS

Biochemical Engineering	Sr

UNIVERSITY OF CALIFORNIA AT DAVIS

Biochemical Engineering Fundamentals	Sr
Chemical Engineering in Integrated Circuit Fabrication Technology	Sr

UNIVERSITY OF CALIFORNIA, SANTA BARBARA

Biochemical Engineering	Sr/S2
Real-time Computing	Sr/S1

CLARKSON UNIVERSITY

Biochemical Engineering	Sr/S2
Integrated Circuit Manufacturing	Sr/S1
Packaging of Electronics	Sr
Microprocessor Applications	Sr/S2

CLEVELAND STATE UNIVERSITY

Biochemical Engineering	Sr
Principles of Solar Engineering	Sr

COLORADO STATE UNIVERSITY

Fundamentals of Biochemical Engineering	Sr/S1
Introduction to Semiconductor Physics and IC Processing	Sr/S1

UNIVERSITY OF COLORADO, BOULDER

Recent Advanced in Biotechnology	Sr
Animal Engineering	Jr
Molecular Basis of Behavior	Sr

CORNELL UNIVERSITY

Microbial Engineering	Sr/S1
Polymers in Electronics and Related Areas	So/S2

DREXEL UNIVERSITY

Microcomputer Applications in Chemical Engr.	Sr
Transport Phenomena in Biological Systems	Sr
Bio-Reactor Engineering	Sr

UNIVERSITY OF NEW BRUNSWICK

Thermodynamics of Waste Heat Recovery	
Nuclear Engineering	
Adsorption and Adsorption Separation Processes	

NEW JERSEY INSTITUTE OF TECHNOLOGY

Introduction to Biochemcial Engineering	Sr/S2
Unit Operations in Food Engineering	Sr/S2
Special Topics in Mass Transfer	Sr/S2

UNIVERSITY OF NEW MEXICO

Semiconductor Phenomena	Jr/S2
VLSI Material Process Technology	Sr/S1
Vacuum Science Technology	Sr/S2

STATE UNIVERSITY OF NEW YORK

Biochemical Engineering	Sr/S1

NORTH CAROLINA STATE UNIVERSITY

Introduction to Biochemical Engineering	Sr

NORTHWESTERN UNIVERSITY

Transport Phenomena in Living Systems	Sr/Q1
Solar Energy Principles and Applications	Sr/Q3
Chemical Process Structures and Information Flows	Sr/Q3

OHIO STATE UNIVERSITY

Novel Separations	Sr
Photochemical and Photoelectrochemical (Utilization of Solar Energy)	Sr

OKLAHOMA STATE UNIVERSITY

Biochemical Engineering	Grad

PENNSYLVANIA STATE UNIVERSITY

Biochemical Engineering	Sr/S2
Separation Processes	Sr/S1

POLYTECHNIC INSTITUTE OF NEW YORK

Fundamentals of Biochemical Engineering	Sr/Q2
Air Pollution Engineering Control	Sr/Q2

PRINCETON UNIVERSITY

Polymers	Sr/S1
Introduction to Fusion Power	Sr/S1
Separations in Biological and Chemical Processes	Sr/S1

PURDUE UNIVERSITY

Biochemical Reactor Engineering	
Fundamentals of Microelectronic Processing	

SUMMARY REPORT

TEACHING OF UNDERGRADUATE FLUID FLOW AND HEAT TRANSFER

A Paper Presented at the

Annual Meeting

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Dr. Edwin O. Eisen, Chairman

McNeese State University

Lake Charles, Louisiana

INTRODUCTION

The 1986 survey examines the teaching of undergraduate Fluid Flow and Heat Transfer. A questionnaire was sent in April, 1986 to the chairmen of 172 chemical engineering departments in the United States and Canada, together with a cover letter asking that appropriate faculty members complete and return the questionnaire. A follow-up letter was sent in late August to those departments which had not responded.

Replies were received from 110 departments. This compares with 110 replies to last year's survey on Process Dynamics and Control and 92 replies to the 1977 survey on Fluid Flow and Heat Transfer.

The questionnaire consisted of three sheets. The first two asked general questions applicable to both heat transfer and fluid flow. The third requested an estimate of time allotments to subject areas for heat transfer and for fluid flow. The replies to the questionnaires are analyzed in this report and are compared, when appropriate, to replies to the 1977 survey.

ANALYSIS OF REPLIES

Respondents to the questionnaires were asked to classify the approach used in teaching the courses as Unit Operations, Transport or a dual approach incorporating significant features of both. 23 departments reported only unit operations approach, while 32 used only the transport approach. Usually, courses were identified as heat transfer or fluid flow courses. However, in several instances a combined course in heat transfer and fluid flow was reported.

Course Characteristics

Approaches	Courses
Unit Operations (U)	Fluid Flow (F)
Transport (T)	Heat Transfer (H)
Dual Approach (D)	Combined Course (C)

In subsequent sections, courses will be classified by two letters, giving the approach and the course. Thus, TF indicates a transport-oriented fluid flow course.

COURSE LEVEL

Table 1 lists the number of courses of each classification taught in each semester and quarter of the sophomore, junior an senior years. The fluid flow course is usually taught before t heat transfer course. 85% of the fluid flow courses are taught in the second semester or third quarter of the sophomore year o the first quarter or first semester of the junior year. Heat transfer follows in the semester or quarter after fluid flow. 90% of the heat transfer courses are given in the two junior ye semesters or the first or second quarters of the junior year.

TABLE 1

COURSE LEVELS

Semester Basis	Fluid Flow			Heat Transfer			Combined		
	UF	TF	DF	UH	TH	DH	UC	TC	DC
Sophomore, Sem 1	1							1	1
Sophomore, Sem 2	7	7	4				1	3	2
Junior, Sem 1	14	15	6	9	9	4	7	5	6
Junior, Sem 2	3		2	8	11	6	4	3	1
Senior, Sem 1		1		2			1	3	
Senior, Sem 2				1	1			1	

Quarter Basis	Fluid Flow			Heat Transfer		
	UF	TF	DF	UH	TH	DH
Sophomore, Qtr 3	3	1	3			
Junior, Qtr 1	2	8	1	1	2	2
Junior, Qtr 2		3		3	4	1
Junior, Qtr 3		1		2	1	
Senior, Qtr 1		1				
Senior, Qtr 2						
Senior, Qtr 3			1			

Table 2 compares the course placements of 1977 and 1986.

Table 2 compares the course placements of 1977 and 1986. It appears that the fluid flow course has been shifted to an earlier semester. The percent of courses in the senior year has decreased by 15 percentage points while the percent of courses in the sophomore year has increased by 14 percentage points. The predominent position for fluid flow remains in the first semester of the junior year.

The heat transfer course has been shifted slightly in both directions. Compared with 1977, there are fewer courses in the first semester of both the junior and the senior year and more courses in the second semester of the junior year. Courses in the first semester has decreased 14 percentage points while the second semester junior year has increased by 17 percentage points.

TABLE 2

COURSE LEVELS

Semester Basis	Fluid Flow	Heat Transfer	Combined
Sophomore Year	32% (18%)	0% (3%)	21%
Junior, Semester 1	58% (56%)	43% (53%)	46%
Junior, Semester 2	8% (15%)	49% (32%)	21%
Senior Year	2% (11%)	8% (12%)	12%

Quarter Basis	Fluid Flow	Heat Transfer
Sophomre Year	29% (7%)	0% (0%)
Junior, Quarter 1	46% (46%)	31% (33%)
Junior, Quarter 2	13% (12%)	50% (39%)
Junior, Quarter 3	4% (23%)	19% (14%)
Senior Year	8% (7%)	0% (14%)

1977 Survey results are in parenthesis.

Table 3 shows the distribution of class enrollments for fluid flow, heat transfer and combined courses. Approximately 60% of the classes had enrollments of 30 or fewer.

TABLE 3

COURSE ENROLLMENTS

Class Size	Fluid Flow	Heat Transfer	Combined
1-10		1	1
11-20	26	26	9
21-30	40	29	16
31-40	16	13	14
41-50	9	14	4
51-60	11	2	3
61-80	7	6	3
80+			1
Average	31.4	30.1	31.1

SYSTEMS OF DIMENSIONS

Since 1979, AIChE has required the use of SI units in all its publications. The 1977 survey indicated that only 1/4 of the courses use English units as the principal system of dimensions; about 2/3 make significant use of both.

This year's survey requested an estimate of the percentage of assignments made (to the nearest 10%) using SI dimensions. In most cases, a single percentage was entered. This was assumed to apply to all courses listed on that questionnaire. In about 20% of the courses, the SI usage in heat transfer and fluid flow was listed separately.

Course	Replies	Weighted average % SI Units
Fluid Flow	20	42.5
Heat Transfer	17	67.1
Both courses	157	58.5

It appears that SI usage is greater in heat transfer than in fluid flow. Just over half the computational effort is carried out in SI dimensions.

TEXTBOOK SELECTION

A total of 28 textbooks were mentioned 186 times in the questionnaires. The five texts listed below account for 67% of all the citations. Of the remaining 23 texts, 9 were cited once, 5 were cited twice and 4 were cited thrice.

Authors	Citations	Percentage
McCabe, Smith, Harriott	39	21%
Bird, Stewart, Lightfoot	30	16%
Bennett, Myers	23	12%
Geankoplis	16	9%
Welty, Wicks, Wilson	15	8%
Others	63	34%

The textbook usage was also analyzed for class approach and course subject matter. The distibution for the Unit Operations approach is shown below:

	UF	UH	UC
McCabe	17	10	9
Bird		1	
Bennett	1		2
Geankoplis	3	4	2
Welty			
Holman		4	
Others	5	7	

For courses using the transport approach, the following distribution was found:

	TF	TH	TC
McCabe			1
Bird	10	8	8
Bennett	5	1	2
Geankoplis	1		2
Welty	4	8	1
Holman		2	
Penn	3		
Incropera		5	
Whitaker	3	1	
Others	11	5	3

In courses using both approaches, the distribution is:

	DF	DH	DC
McCabe	2		
Bird	2	1	
Bennett	5	4	3
Geankoplis	2		4
Welty	1	1	
Holman		4	
Others	5	3	2

COURSE STRUCTURE

Approximately two dozen topics were selected from textbooks frequently used in heat transfer and fluid flow courses. Instructors were asked to show the number of class sessions spent on the respective topics and to other topics. The results were added and normalized to a 40-session course plan. This is equivalent to a 15-week course meeting three times a week, with 5 sessions for quizzes. Replies to this section of the questionnaire were received on 94% of the heat transfer responses and 94% of the fluid flow responses. The Topic Time Allocations are given on the following pages.

Comparison of the 1986 and 1987 time allocations shows few changes. The present flow flow course shows increases of 0.4 sessions in flow equations and 0.6 sessions in non-newtonian flow and a decrease of 0.5 sessions in ideal flow. The heat transfer course shows increase of 0.4 sessions in one-dimensional conduction, in unsteady-state conduction and in boundary layer theory. There are decreases of 0.4 sessions in radiation and in heat exchangers. Approximately 8-10% of the classtime is devoted to topics other than those listed.

The additional topics most often mentioned in fluid flow are:

Agitation and mixing
Flow through packed beds
Flow past solid objects
Fluidization
Filtration

Principal additional topics in heat transfer include:

Numerical methods in unsteady state
Evaporation
Multipass heat exchangers
Finite difference methods in steady state

FLUID FLOW

TIME ALLOCATIONS
(Sessions of 50 Minutes Each)

	1986		1977	
Properties/Definitions		1.9		1.8
Viscosity; Mass, Force Units	1.9		1.8	
Fluid Statics		3.0		3.0
Manometers	1.1		1.3	
Buoyancy, Flotation	0.9		0.6	
Plane Surfaces	0.6		0.8	
Curved Surfaces	0.4		0.3	
Flow Equations		8.0		7.6
Continuity	2.1		2.3	
Bernoulli	2.8		2.7	
Conservation of Momentum	3.0		2.6	
Incompressible Flow		11.7		11.8
Laminar/Turbulent Flow	3.4		3.8	
Friction Factors	2.3		2.0	
Equivalent Length of Fittings	1.2		1.0	
Boundary Layer, Velocity Distribution	2.6		2.5	
Piping Systems	2.3		2.5	
Compressible Flow		2.2		2.3
Isothermal	0.7		0.8	
Isentropic	0.6		0.7	
Non-isothermal	0.5		0.5	
Sonic Velocity	0.4		0.3	
Ideal Fluid Flow	1.1	1.1	1.6	1.6
Dimensional Analysis	1.9	1.9	2.0	2.0
Non-Newtonian Fluids	1.6	1.6	1.0	1.0
Fluid Measurement		2.9		2.8
Orifice, Venturi	1.7		1.9	
Pitot tube, others	1.2		0.9	
Fluid Machinery		2.2		2.2
Pumps	1.6		1.8	
Turbines	0.6		0.4	
Other Topics	3.5	3.5	3.9	3.9
TOTAL	40.0	40.0	40.0	40.0

HEAT TRANSFER

	1986		1977	
Dimensional Analysis	1.6	1.6	1.6	1.6
Steady State Conduction in One Dimension		7.1		6.6
Plane Systems	2.3		2.2	
Radial Systems	1.9		1.8	
Heat Source Systems	1.3		1.2	
Fins	1.6		1.4	
Steady State Conduction in Two Dimensions		1.5		1.2
Curvilinear Squares	0.9		0.6	
Relaxation	0.6		0.6	
Unsteady State Conduction		3.0		2.6
Lumped Heat Capacity	1.4		1.4	
Heisler Charts	1.2		0.8	
Schmidt Plot	0.4		0.4	
Boundary Layer Theory	2.2	2.2	1.8	1.8
Forced Convection Correlations		5.3		5.4
Pipes/tubes	2.7		3.0	
Cylinders/spheres	1.4		1.4	
Tube banks	1.3		1.0	
Natural Convection Correlations		3.0		3.3
Flat Plates	1.1		1.2	
Cylinders/spheres	0.9		1.1	
Combines Natural & Forced Convection	0.9		1.0	
Radiation		4.8		5.2
Mechanism	1.5		1.7	
Shape Factors	1.2		1.6	
Gray Bodies	1.1		1.2	
Gas Radiation	0.5		0.4	
Solar Radiation	0.5		0.3	
Phase Change		2.8		2.9
Condensation	1.6		1.6	
Boiling	1.2		1.3	
Heat Exchangers		5.8		6.2
Overall Coefficient	2.3		2.6	
Fouling Factors	1.1		1.1	
Shell Side Coefficients	1.5		1.6	
Pressure Drops	0.9		0.9	
Other Topics	2.9	2.9	3.2	3.2
TOTAL	40.0	40.0	40.0	40.0

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Holman, "Heat Transfer", 6th ed., McGraw-Hill, 1986.

INSTRUCTOR ____________________ UNIVERSITY ____________________

PART I

COURSE NO.	COURSE TITLE	PLACE IN CURRICULUM Year/Semester
1.		
2.		
3.		

COURSE NO.	TEXT (Author, Title)	1985-86 Sections	Avg. Enroll	Hrs. Design
1.				
2.				
3.				

1. Weeks per quarter/semester __________

2. Do you use any films, videotapes or demonstrations in the classroom? If so, please elaborate.

3. How do you incorporate design into these courses?

UNIVERSITY ______________________________

1. What percentage of the assigned problems use SI (rather than English) dimensions? Express to the nearest 10%.

2. Is this text also the principal text for another course? If so, please give course title.

3. Would you classify the text as unit operations oriented (eg. McCabe and Smith) or transport phenomena oriented (eg. Bird, Stewart and Lightfoot)?

4. Are the heat transfer/fluid flow courses for chemical engineers only, or can other engineering students enroll?

5. Does your department offer a chemical engineering laboratory course with credit separate from the Heat Transfer or Fluid Flow lecture courses? If so,

   a). How many courses ______________

   b) Contact hours per course per week ______________

6. What topics, if any, seem particularly difficult for the student to grasp?

7. What topics, not included in the present text, would you like to see included?

The following pages summarize replies to three questions on the questionnaire.

1. What films or other visual aides are used in the classroom? (FILMS)

2. How do you incorporate design within the curriculum? (DESIGN)

3. What topics do students seem to have particular difficulty with? (DIFFICULT TOPICS)

NEW YORK POLYTECHNIC UNIVERSITY-BROOKLYN

DESIGNS: Problem.

DIFFICULT TOPICS: Velocity and shear stress distribution from shell balances.

STATE UNIVERSITY OF NEW YORK AT BUFFALO

DESIGNS: Open-ended problems.

NORTH CAROLINA STATE UNIVERSITY

DESIGNS: Yes.

UNIVERSITY OF NORTH DAKOTA

DESIGNS: Computer problems.

DIFFICULT TOPICS: Fluid Flow.

TECHNICAL UNIVERSITY OF NOVA SCOTIA

DESIGNS: Through the course in Process Plant Design.

DIFFICULT TOPICS: Momentum balance, resistance concept, boundary layer analysis.

OHIO UNIVERSITY

FILMS: Filmstrips: National Committee for Fluid Mechanics Films.

DESIGNS: Short problems (2-6 hrs.).

DIFFICULT TOPICS: Piping networks, radiation heat transfer and adding resistances.

OHIO STATE UNIVERSITY

FILMS: Fluid Mechanics

DESIGNS: Heat exchanger design.

DIFFICULT TOPICS: Navier-Stokes equation, radiation.

OKLAHOMA UNIVERSITY

FILMS: Turbulent flow.

DESIGNS: Problem assignments.

DIFFICULT TOPICS: Correlations.

OREGON STATE UNIVERSITY

FILMS: Fluid Mechanics

DESIGNS: Open-ended problems (weekly).

DIFFICULT TOPICS: Boundary layer theory, turbulent flow.

PENNSYLVANIA STATE UNIVERSITY

DESIGNS: Open-ended problems.

DIFFICULT TOPICS: Navier-Stokes Equation, differential energy balance equation in flow systems.

UNIVERSITY OF PENNSYLVANIA

DIFFICULT TOPICS: Reduction of partial differential equations.

UNIVERSITY OF PITTSBURGH

DESIGNS: Problems.

DIFFICULT TOPICS: Unsteady state problems, concept of turbulence.

PRAIRIEVIEW A & M

DESIGNS: Problems.

DIFFICULT TOPICS: Bulk flow in diffusion problems, turbulent flow. Eddie's trial & Error solutions.

PRINCETON UNIVERSITY

FILMS: Fluid Mechanics (4)

DESIGNS: Problem sets.

UNIVERSITY OF PUERTO RICO

DESIGNS: Problems on pipes & flowmeters design project of heat exchanger piping systems or networks.

DIFFICULT TOPICS: Turbulent flow & equivalent lengths of fittings.

PURDUE UNIVERSITY

DIFFICULT TOPICS: Several topics.

RENSSELAER POLYTECHNIC INSTITUTE

DESIGNS: Open-ended problems.

DIFFICULT TOPICS: Momentum Theorem, Equation of Motion.

UNIVERSITY OF RHODE ISLAND

DESIGNS: Problem solving.

DIFFICULT TOPICS: Heat transfer concepts, differential momentum equation.

RICE UNIVERSITY

DIFFICULT TOPICS: Navier-Stokes Equations, turbulence, boundary layer flow.

ROSE-HULMAN INSTITUTE OF TECHNOLOGY

DIFFICULT TOPICS: Convective heat transfer.

RUTGERS-THE STATE UNIVERSITY

DESIGNS: Short open-ended problems, heat exchanger design.

DIFFICULT TOPICS: Bulk flow effects, boundary layer theory.

UNIVERSITY OF SASKATCHEWAN

DESIGNS: Problem selection.

DIFFICULT TOPICS: Partial derivative momentum equations, Reynolds stresses.

SCHOOL OF MINES AND TECHNOLOGY

DESIGNS: Not stressed.

DIFFICULT TOPICS: Momentum transfer, unsteady state conduction equations.

STANFORD UNIVERSITY

FILMS: Fluid Mechanics.

DESIGNS: Problem sets.

DIFFICULT TOPICS: Vectors, basic physics, physical interpretation math formulas.

STEVEN'S INSTITUTE OF TECHNOLOGY

DESIGNS: Special assignments.

DIFFICULT TOPICS: Mathematical Fundamentals in an applied setti[illegible]

TENNESSEE TECHNOLOGICAL UNIVERSITY

DIFFICULT TOPICS: Radiation-unsteady state heat transfer.

TEXAS A & M UNIVERSITY

DESIGNS: Short design problems.

DIFFICULT TOPICS: Momentum balance & ultrasonic flow.

TEXAS A & M UNIVERSITY

DESIGNS: Problems (heat exchanger, pump).

DIFFICULT TOPICS: Non-Newtonian properties.

TEXAS TECH UNIVERSITY

DESIGNS: Pump design, heat exchanger design.

DIFFICULT TOPICS: Navier-Stokes, tensor analysis, flow assumptions, derivations of differential equations from model.

UNIVERSITY OF TEXAS/AUSTIN

DESIGNS: Piping & heat exchanger arrays optimization.

UNIVERSITY OF TOLEDO

DESIGNS: Open-ended problems.

DIFFICULT TOPICS: Shear stress, momentum transfer.

TUFT"S UNIVERSITY

DESIGNS: Open-ended problems.

DIFFICULT TOPICS: Meaning of momentum transport relative to heat and mass.

TULANE UNIVERSITY

DIFFICULT TOPICS: Flow net works, combined conduction and convection or radiation trial and error problems.

UNIVERSITY OF TULSA

DESIGNS: Problems-pipe exchangers, insulation.

TUSKEGEE UNIVERSITY

DESIGNS: Open-ended problems.

DIFFICULT TOPICS: Compressible fluids.

UNIVERSITY OF VILLANOVA

FILMS: National Committee for Fluid Mechanics Films.

DESIGNS: Homework problems.

DIFFICULT TOPICS: Non-Newtonian fluids, surface tension, pump-pipeline system operation.

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

DESIGNS: Open-ended problems.

DIFFICULT TOPICS: Modelling in general, unsteady state heat transfer.

UNIVERSITY OF VIRGINIA

DESIGNS: Problem sessions.

DIFFICULT TOPICS: Notion that correlations are not perfect and that real world measurements don't have 9-10 significant figures.

UNIVERSITY OF WASHINGTON

FILMS: Fluid Mechanics (3)

DESIGNS: Problems.

DIFFICULT TOPICS: Radiation and turbulence.

UNIVERSITY OF WATERLOO

FILMS: Fluid flow.

DESIGNS: Assignments.

DIFFICULT TOPICS. Thermal radiation.

UNIVERSITY OF WEST VIRGINIA TECH

FILMS: Fluid Flow Phenomena

DESIGNS: Project, small design type homework problems.

DIFFICULT TOPICS: Boundary layer flow.

WEST VIRGINIA UNIVERSITY

FILMS: Slides on heat exchangers, filmstrips (MIT).

DESIGNS: Project, design assignments.

WESTERN ONTARIO UNIVERSITY

FILMS: Fluid Flow.

WIDENER UNIVERSITY

DESIGNS: Open-ended problems.

DIFFICULT TOPICS: Differential balances, bondary layer theory, unsteady state conduction.

WORCHESTER POLYTECHNIC INSTITUTE

DIFFICULT TOPICS: Radiation, compressible flows.

UNIVERSITY OF WYOMING

DESIGNS: Heat exchanger and pipe design.

YOUNGSTOWN STATE UNIVERSITY

DESIGNS: Short problems.

DIFFICULT TOPICS: Momentum balances, Non-Newtonian fluids, unsteady state balances.