NUCLEAR ENGINEERING

MASSACHUSETTS INSTITUTE
OF TECHNOLOGY

The 1994 MIT NED-DOE Intern Program

Report MITNE-308

J.E. Meyer, Program Director

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THE 1994 PROGRAM AND FUTURE PLANS

This report[1] describes a special educational program for DOE interns that was offered at MIT in 1994. The program started at the beginning of August and will continue until a time in the Fall Term Final Exam Period (about mid-December). Many details of this program (including lists of day-by-day lecture topics) are supplied in order to clarify the approaches for meeting academic objectives.

In planning future related educational programs, it is clear that several options are available for consideration:

a) August-Fall Basis: This option is based on planning a new program that repeats essentially the same sequence at the same times of the year. That is, August is used as a preparation phase and the Fall Term for regular courses. This arrangement seemed satisfactory in 1994. An improved mathematics coverage should also be considered. This coverage could be achieved by moving the starting date to mid-July to accommodate mathematics in July or by substituting early-August mathematics for some of the existing subject matter.

b) January-Spring Basis: This option is based on a substitution of a preparation phase during January (MIT's Independent Activities Period) for that during August. The Spring Term regular courses would substitute for those in Fall Term. Some adjustment in course selection, or some need to fund additional course sections, would be required. These changes are caused by the present practice of teaching many subjects only once a year.

c) Master of Engineering Degree Program: For this option, all participants would be accepted in the Nuclear Engineering Department graduate school. Regular courses, a team project, and a practical thesis would be completed. A Master of Engineering Degree would typically be awarded after a stay at MIT of one year. Some details remain undefined for this program, but it is expected that a very satisfying educational approach can be obtained.

THE 1994 PROGRAM

All participants in the 1994 program were DOE employees. They had been hired to become part of a select group of recent engineering graduates. It is expected that members of the group will, with suitable training, be likely candidates for DOE leadership roles in positions requiring technical competency. After being hired, each group member spends 2½ years to get academic training and industry/national laboratory experiences. The NED-DOE Program

[1] The MIT NED-DOE acronyms indicate Massachusetts Institute of Technology Nuclear Engineering Department - Department of Energy.

has contributed to a portion of the academic training; the portion is intended to strengthen engineering skills (especially nuclear engineering skills).

The existing NED-DOE Program has two major parts -- the August Program (preparation phase) and the Fall Term Program (regular courses):

- August Program -- This part provides a review of engineering principles at an advanced undergraduate level. It equips participants with fundamentals in preparation for fall term subjects. It permits some students to learn topics outside their previous degree specialty; it permits other students to upgrade skills within their specialty.

  The courses in the August Program are specially designed for the NED-DOE Program and are attended only by DOE interns. The courses are taken in a summer session non-degree manner.

- Fall Term Program -- This part utilizes four regular fall term graduate courses in the School of Engineering. The courses are chosen to be suitable as background for enhancing technical competency in potential DOE leadership roles.

  The interns join regular graduate students during classroom lectures. The interns also complete all course requirements and grading activities. They must be admitted to MIT as "Special Graduate Students" and the courses are completed in a non-degree manner.

In 1994, four interns completed the August Program and three continued into the Fall Term Program (the fourth left MIT to participate in other DOE training activities).

Many of the details for participating in, planning, and executing these Programs are provided in the pages that follow.

THE AUGUST PROGRAM

The August Program consists of five courses; each course is indicated in the following pages by a two-letter symbol. The first three courses are devoted to Engineering Principles; the next, to Physics Fundamentals; and the fifth, to Radiation Protection:

- Th = Thermodynamics, Fluid Flow, and Heat Transfer (Thermofluids);
- St = Structural Mechanics;
- Mt = Physical Metallurgy;
- Ph = Physics Fundamentals; and
- Rp = Principles of Radiation Protection.

More information on the August Program courses is provided in the Appendix:

- Table 1 gives the number of lectures (1½ hours each) and lists the cognizant teaching personnel.
- Table 2 shows the daily schedule for lectures. There are two lectures for each of twenty days.
- Table 3 gives a lecture-by-lecture syllabus for each of the courses.

A graduate student (Gary S. Cerefice) worked both for participants and for lecturers. He attended all lectures; he was available for answering questions; and he served in a Teaching Assistant role.

THE FALL TERM PROGRAM

The Fall Term Program consists of four courses. They are taken by each program participant after being accepted as a special graduate student. Some regular MIT graduate students also will be enrolled in each of these courses. The courses (and cognizant teaching personnel) are:

- 22.111 = Nuclear Physics for Engineers I (Kevin W. Wenzel, Assistant Professor of Nuclear Engineering);
- 22.312 = Engineering of Nuclear Reactors (Neil E. Todreas, Professor of Nuclear and Mechanical Engineering);
- 22.77 = Nuclear Waste Management (Man-Sung Yim, Lecturer, Nuclear Engineering); and
- 22.904 = Management and Organization of Complex Organizations (John S. Carroll, Professor, Sloan School of Management).

A lecture-by-lecture syllabus for these courses is provided in Table 4 in the Appendix.

As a part of the Fall Term Program, four special seminars have been arranged that cover topics of special DOE interest:

1) "N-Reactor Follies" by Ronald G. Ballanger, Associate Professor, Nuclear Engineering.

2) "DOE New Production Reactor" by Neil E. Todreas, Professor, Nuclear Engineering and Mechanical Engineering.

3) "Hanford Tanks High Level Waste Issues" by Mujid S. Kazimi, Professor and Head, Nuclear Engineering Department.

4) "Disposition of Plutonium" by Dr. Marvin M. Miller, Senior Research Scientist, Nuclear Engineering.

A graduate student (Sarah A. Abdelkader) is working both for participants and for the program director. She is available for answering participant questions (both about academic matters and about interactions with the department and MIT). She has made arrangements for the special seminar series and has gathered material for this report.

CONCLUSIONS ABOUT THE 1994 PROGRAMS

We judge that the August Program provided an appropriate preparation for the Fall Term. The tone and pace of the classes were similar to the regular Fall courses. In two courses ("Physics Fundamentals" and "Principles of Radiation Protection"), the similarity was especially strong. In these cases, the August instructors also taught courses that are part of the Fall Program.

The August Program seemed also to be appropriate for enabling some students to learn topics outside their previous degree specialty and for permitting other students to upgrade skills within their specialty.

The Fall Program utilizes four regular fall term graduate courses in the School of Engineering. The program is presently a little over halfway complete. However, it seems that the course content and the workload are appropriate. The courses are expected to be suitable as background for enhancing technical competency in potential DOE leadership roles.

The participants feel that an aspect to be improved in future versions of these programs relates to mathematical content. Books, notes, and lectures are prepared using the assumption that each participant has a currently active ability to follow advanced mathematical arguments. It was suggested that some time should be spent at the beginning of the August Program to upgrade mathematical skills. It was also suggested that this topic could be substituted for the Electricity and Magnetism portion of the Physics Fundamentals. These suggestions have been considered when writing the first few paragraphs in this report ("The 1994 Program and Future Plans").

APPENDIX

This Appendix contains four tables with details of the NED-DOE programs:

Table 1: August Program Courses and Cognizant Personnel

Table 2: August Program Schedule

Table 3: Curricula of the August Program Courses

Table 4: Curricula of Courses in the Fall Term

TABLE I: AUGUST PROGRAM COURSES (and Cognizant Personnel)

	Lectures (1½ hrs each)
Engineering Principles	
Th = Thermodynamics, Fluid Flow, and Heat Transfer (Thermofluids) (Ali Shajii, Sponsored Research Staff, Plasma Fusion Center)	8
St = Structural Mechanics (John Meyer, Professor, Nuclear Engineering)	5
Mt = Physical Metallurgy (Ronald Ballinger, Associate Professor, Nuclear Engineering)	7
Physics Fundamentals	
Ph = Electricity & Magnetism, Atomic Physics, and Nuclear Physics (Kevin Wenzel, Assistant Professor, Nuclear Engineering)	12
Principles of Radiation Protection[2]	
Rp = Health Physics, Environmental Problems, and Radioactive Waste Management	
(Man-Sung Yim, Lecturer, Nuclear Engineering;	6
Otto K. Harling, Professor, Nuclear Engineering;	1
Francis X. Masse, Radiation Protection Officer, MIT Medical)	1
Total Lectures August Program	40

2 Underpinnings for Radioactive Waste Management and Environmental Remediation

TABLE 2: AUGUST PROGRAM SCHEDULE[3]

The two-letter course notations are explained adjacent to Table 1. The numbers indicate the sequence of lectures (e.g., St 1 through St 5 denote the five Structural Mechanics lectures).

Day 1994		Lecture	
08/01	Mon	Ph 1	St 1
08/02	Tue	Rp 1	Th 1
08/03	Wed	Ph 2	St 2
08/04	Thu	Rp 2	Th 2
08/05	Fri	Ph 3	St 3
08/08	Mon	Ph 4	St 4
08/09	Tue	Rp 3	Th 3
08/10	Wed	Ph 5	St 5
08/11	Thu	Rp 4	Th 4
08/12	Fri	Ph 6	Mt 1
08/15	Mon	Ph 7	Mt 2
08/16	Tue	Rp 5	Th 5
08/17	Wed	Ph 8	Mt 3
08/18	Thu	Rp 6	Th 6
08/19	Fri	Ph 9	Mt 4
08/22	Mon	Ph 10	Mt 5
08/23	Tue	Rp 7	Th 7
08/24	Wed	Ph 11	Mt 6
08/25	Thu	Rp 8	Th 8
08/26	Fri	Ph 12	Mt 7
08/29	Mon	Study Period	
08/30	Tue	" "	
08/31	Wed	Final Exams	
09/01	Thu	" "	
09/02	Fri	Vacation	
09/05	Mon	" "	
09/06	Tue	Registration Day--Fall Term	
09/07	Wed	First Day of Classes--Fall Term	

3 A nominal schedule is given in Table 2 and essentially is as taught. The actual teaching pattern varied in a minor manner to permit some teaching personnel to satisfy other commitments.

TABLE 3: CURRICULA OF THE AUGUST PROGRAM COURSES[4]

Thermodynamics, Fluid Flow, and Heat Transfer (Thermofluids): This course was scheduled for two lectures per week for all four weeks of the August Program. Lecture topics are as follows (the classes are numbered Th 1 through Th 8, and each class is 1½ hours' duration):

Class #	Lecture Topic
Th 1 & Th 2	Heat Transfer by Conduction in Solids.
Th 3 & Th 4	Introduction to Thermodynamics
Th 5 & Th 6	Fluid Dynamics
Th 7 & Th 8	Complex Systems Involving Both Fluid Dynamics and Heat Transfer

Structural Mechanics: This course was scheduled for three lectures during the first week and two lectures during the second week of the August Program.[5] Lecture topics are as follows (the classes are numbered St 1 through St 5, and each class is 1½ hours' duration):

Class #	Lecture Topic
St 1	Fundamental Mechanical Tests
St 2	Elasticity Fundamentals
St 3	Pressure Vessel Stress Analysis
St 4 & St 5	Design Limits (ASME Code and ASME Code Cases)

Physical Metallurgy: This course was scheduled for one lecture during the second week and three lectures during each of the last two weeks of the August Program. Lecture topics are as follows (the classes are numbered Mt 1 through Mt 7, and each class is 1½ hours' duration):

Class #	Lecture Topic
Mt 1	Materials Selection
Mt 2	Basic Metallurgy
Mt 3	Basic Metallurgy and Radiation Damage
Mt 4	Radiation Effects
Mt 5	Fuels
Mt 6	Structural Materials
Mt 7	Environmental Effects

4 Table 3 contains the nominal syllabus for each August Program course. The description in Table 3 is essentially correct. However, the actual teaching pattern may differ slightly to permit improved emphases and mid-course adjustments.

5 Note that the Final Exam in this course was given during the third week of the August Program rather than at the end.

Physics Fundamentals: This course was scheduled for three lectures during each of the four weeks of the August Program. Lecture topics are as follows (the classes are numbered Ph 1 through Ph 12, and each class is 1½ hours' duration):

Class #	Lecture Topic
	----- Electromagnetism -----
Ph 1	Introduction to Electromagnetism
Ph 2	Maxwell's Equations
Ph 3	Wave Propagation in Free Space
Ph 4	Wave Propagation in Material Media
	----- Atomic Physics -----
Ph 5	Experimental Background and Basis
Ph 6	Quantum Mechanics: Photons as Particles
Ph 7	Quantum Mechanics: Particles as Waves
Ph 8	Atomic Structure
	----- Nuclear Physics -----
Ph 9	Nuclear Structure
Ph 10	Nuclear Properties
Ph 11	Radioactive Decays
Ph 12	Nuclear Reactions

Principles of Radiation Protection: This course was scheduled for two lectures during each of the four weeks of the August Program. Lecture topics are as follows (the classes are numbered Rp 1 through Rp 8, and each class is 1½ hours' duration):

Class #	Lecture Topic
	----- Health Physics -----
Rp 1	Basics of Radiation
Rp 2	Biological Effects of Radiation
Rp 3	Radiation Dosimetry
Rp 4	Radiation Detection and Measurements
Rp 5	Radiation Protection Standards
	----- Environmental Problems and Radioactive Waste Management -----
Rp 6	Sources and Uses of Radiation
Rp 7	High Level Radioactive Waste Management
Rp 8	Low Level Radioactive Waste Management

TABLE 4: CURRICULA[6] OF COURSES IN THE FALL TERM

22.111 Nuclear Physics for Engineers I This is an advanced level (H-Level) graduate course rated at 12 units. It is required for all regular graduate students in nuclear engineering. The grading basis is:

Homework	35%
Quizzes	35%
Final Exam	30%

Lecture topics are as follows (the classes are numbered 1 through 38 and each class is 1 hour duration):

Class #	Lecture Topic
1	Introduction: Basic Nuclear Concepts
2	Why Quantum Mechanics?
3	Quantum Postulates
4	Function Spaces & Operators
5	Superposition & Commutation
6	Time Dependence: Parity
7 & 8	1-D Problems, Square Wells, Tunneling
9	Angular Momentum
10	QUIZ 1
11	Magnetic Resonance Imaging
12 & 13	Nuclear Binding Energy
14 & 15	Nuclear Force and Structure
16 & 17	Nuclear Models; Shell Model
18	Radioactive Decay
19 & 20	α-Decay
21 & 22	β-Decay
23 & 24	γ-Decay
25	Review Session
26	QUIZ 2
27	Solar Neutrinos
28 & 29 & 30	Charged-Particle Interactions
31 & 32	γ-Ray Interactions
33 & 34	Neutron Interactions
35	QUIZ 3
36	Nuclear Reactions

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6 Table 4 contains the nominal syllabus for each course in the Fall Term Program. The description in Table 4 is essentially correct. However, the actual teaching pattern may differ slightly to permit improved emphases and mid-term adjustments. In addition, one or two unscheduled classes exist in some cases to permit additional improvements in teaching material.

22.111 continued

37	Fission
38	Fusion
--	FINAL EXAM

22.312 Engineering of Nuclear Reactors This is an advanced level (H-Level) graduate course rated at 12 units. It provides a thorough drill in the fundamentals of fluid flow, heat transfer, thermodynamics, and structural mechanics with application examples appropriate for nuclear engineering students. The grading basis is:

Homework	20%
Quizzes	40%
Final Exam	40%

Lecture topics are as follows (the classes are numbered 1 through 25, and each class is 1½ hours' duration):

Class #	Lecture Topic
1	Course Introduction and Reactor Types
2	Thermal Design Principles
3	Reactor Heat Generation (including Zr -Steam, Core-Concrete, Combustion)
4 thr 7	Reactor Power Cycles
8 & 9	Containment Pressurization
10 thr 12	Thermal Analysis of Fuel Elements
13	QUIZ 1
14	Finish: Thermal Analysis of Fuel Elements Start: Max Core Fuel & Coolant Temperatures
15	Energy Equation
16	Single-Phase Fluid Mechanics
17	Single-Phase Heat Transfer
18	Finish: Single-Phase Heat Transfer and Fluid Mechanics
19	Two-Phase Fluid Mechanics
20 & 21	Two-Phase Heat Transfer
22	QUIZ 2
23 & 24	Elasticity Fundamentals
25	Simple Mechanical Tests and Pressure Vessel Design
--	FINAL EXAM

22.77 Nuclear Waste Management This is an advanced level (H-Level) graduate course rated at 12 units. It introduces scientific/engineering aspects of managing spent fuel, reprocessed high-level waste, uranium mill tailings, low-level wastes, and decommisioning wastes. The grading basis is:

Homework	10%
Quizzes	70%
Term Project & Term Paper	20%

Lecture topics are as follows (the classes are numbered 1 through 24 and each class is 1½ hours duration):

Class #	Lecture Topic
1	Course Outline/Sources and Classifications of Radioactive Wastes
2	Nuclear Reactions and Radioactive Decay
3	Regulations/Radiation Protection Standards
4	Radioactive Wastes from Nuclear Fuel Cycle
5	Characteristics of Spent Fuel & Its Management & Disposal
6	Geologic Disposal of High-Level Waste (HLW)
7 & 8	Groundwater Hydrology
9 & 10	Radionuclide Transport
11	Geochemistry
12	Waste Packages
13	QUIZ 1
14	Finish: Waste Package; Start: Waste Forms
15	Repository Thermal Phenomena/HLW Total System; Performance Assessment
16	Defense Waste; Environmental Remediation
17	Actinide Burning & Transmutation
18	Overview of Management of Low-Level Waste (LLW)
19	LLW Treatment Technologies
20	Performance Assessment of LLW Facilities
21	Decontamination & Decommissioning
22	Current Issues in LLW Management (Current State Compacts Situation, Waste Minimization, BRC, Mixed Wastes, etc.)
23	QUIZ 2
24 & 25	Term Paper Presentations

22.904 and 15.328 Management and Organization of Complex Organizations This is a graduate level (G-Level) course rated at 6 units. It is a new course that has grown out of MIT Sloan/NED research aimed at guiding the management of a complex, high-hazard, regulated industry in a changing environment. The grading basis is:

Class Participation	50%
Term Paper	50%

Lecture topics are as follows (the classes are numbered 1 through 12 and each class is 2 hours' duration):

Class #	Lecture Topic
1	Introduction
2	Organizations Overview
3	Groups
4	Motivation and Careers in Organizations
5	Human Error
6	Learning from Experience
7	Leadership and Power
8	Organization Design--Reengineering, TQM
9	Culture
10	Institutions and Industrial Policy
11	Learning Organization
12	Discussion Student Papers; Final Discussion

END OF TABLE 4