Chapter 1 Course Overview

1.1 Introduction

This course is concerned with thermal hydraulic analysis of the process systems that are required to transport heat energy away from the nuclear reactor source and transform this heat energy into useful work (generally electrical energy). Thermal hydraulic design of the process systems is covered in a separate course. Design and analysis are, of course, tightly coupled. Nuclear systems design is guided by analysis results. Analysis, in turn, is performed on a specific design to determine its performance. It is a complex, iterative dance. Design and analysis of the reactor process involves a number of interrelated systems:

reactor core
heat transport system
steam generators
turbines
pressure control system
coolant inventory control systems
power control systems;

a number of system components:

valves
pumps
pipes
vessels
heat exchangers;

and a number of engineering and science disciplines:

reactor physics
heat transfer
fluid mechanics
thermodynamics
chemistry
metallurgy
control
stress analysis.

The heat transport system (HTS) is of central importance since it is the interface between the heat source and the heat sink. Good HTS performance is essential to reactor integrity, plant performance and safety. Herein, the scope is limited to the modelling tools used in thermal hydraulic analysis of the HTS. This course is a systems level course, not a components level one. Component modelling is limited to approximate models that are appropriate for systems analysis. Detailed multidimensional modelling of complex components such as steam generators, pumps, calandria vessels, headers, etc., are not attempted.

Figure 1.1 provides an overview of the main concepts covered in this course and the relationships between these concepts. This course is primarily about the interplay the two main actors in hydraulic systems: flow and pressure. But because we are dealing with systems involving the transfer of heat, local density and enthalpy determine the pressure. Hence, thermal hydraulic system behaviour is largely determined by the simultaneous solution of the equations that govern these four variables (flow, pressure, density and enthalpy).

1.2 Learning Outcomes

In each chapter the course objectives (learning outcomes) are set down. Learning by objectives has received some "bad press" since some lecturers have a tendency to be overly specific in their statement of objectives and some students have a tendency to be overly narrow in their learning of only that explicitly stated in the objectives. This is, of course, inappropriate. Herein, the tone of the objective statements is set to be specific enough to serve as a guide to expectations but not so specific as to be questions in disguise. The outcomes are meant to be a guide for the student and teacher alike. The list is by no means exhaustive but it is hoped that it is complete enough to indicate the type and extend of learning to be mastered.

The classifications in the objective statements refer to Bloom's taxonomy [BLO71] for the cognitive domain as given in figure 1.2. These classifications are important in that they indicate the type of understanding that is to occur, ie, whether the student is to just memorize facts or is to achieve some higher level mental ability. The weight of each classification is

a = "must"
b = "should"
c = "could"

indicating the importance of the objective to the understanding of the overall course.

The objectives are keyed to the concepts to be learned and not to specific course content since the content is just one of many ways to elicit understanding in the student.

The overall objectives for the course are as follows:

Objective 1.1	The student should be able to explain the overall theme of the course and relate the roles played by mass, flow, energy and pressure in thermalhydraulic simulation.					
Condition	Closed book written or oral examination.					
Standard	100% on definition and units, answer may be given using word descriptions, diagrams or graphs as appropriate.					
Related concept(s)	Overall concept map for the course					
Classification	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Weight	a	a	a			

Objective 1.2	The student should be able to derive appropriate forms of the governing equations, and develop a flow diagram and pseudo-code for a thermalhydraulic system simulator from first principles.					
Condition	Open book.					
Standard	100% on flow diagram and pseudo-code.					
Related concept(s)						
Classification	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Weight	a	a	a	a		a

Objective 1.3	The student should be able to build a thermalhydraulic system simulator from first principles.					
Condition	Workshop or project based investigation.					
Standard	The code should work. Any programming language is acceptable.					
Related concept(s)						
Classification	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Weight	a	a	a			

1.3 The Course Layout

To lay the groundwork for thermal hydraulic systems analysis, Chapter 2 presents the general mass, energy and momentum conservation equations in very general terms and proceeds to derive the common approximate forms used in systems modelling. Chapter 3 shows how to model hydraulic piping networks as a system of nodes connected by links and elaborates on the appropriate equation forms for these node-link approximations. The conservation equations requires a relationship between pressure, temperature, density and energy (the equation of state) for closure. In Chapter 4, the equation of state is explored with particular emphasis on implementation. Chapters 5 and 6 cover numerical considerations. Explicit, semi-implicit and implicit techniques are presented. At this point the reader is almost ready to conduct thermal hydraulic simulations. Chapter 7 completes the picture by providing rudimentary heat transfer and hydraulic correlations that are needed for the simulations. Chapter 8 provides closure with a general look at some codes used by the industry.

As with design, there is no one best model for a given analysis task, nor is there even one best solution procedure. Good simulation is evolutionary; we learn from past successes and failures, incorporate the latest experimental, theoretical and numerical results, employ sound engineering principles and a solid understanding of the basics to engineer each and every new simulation tool.

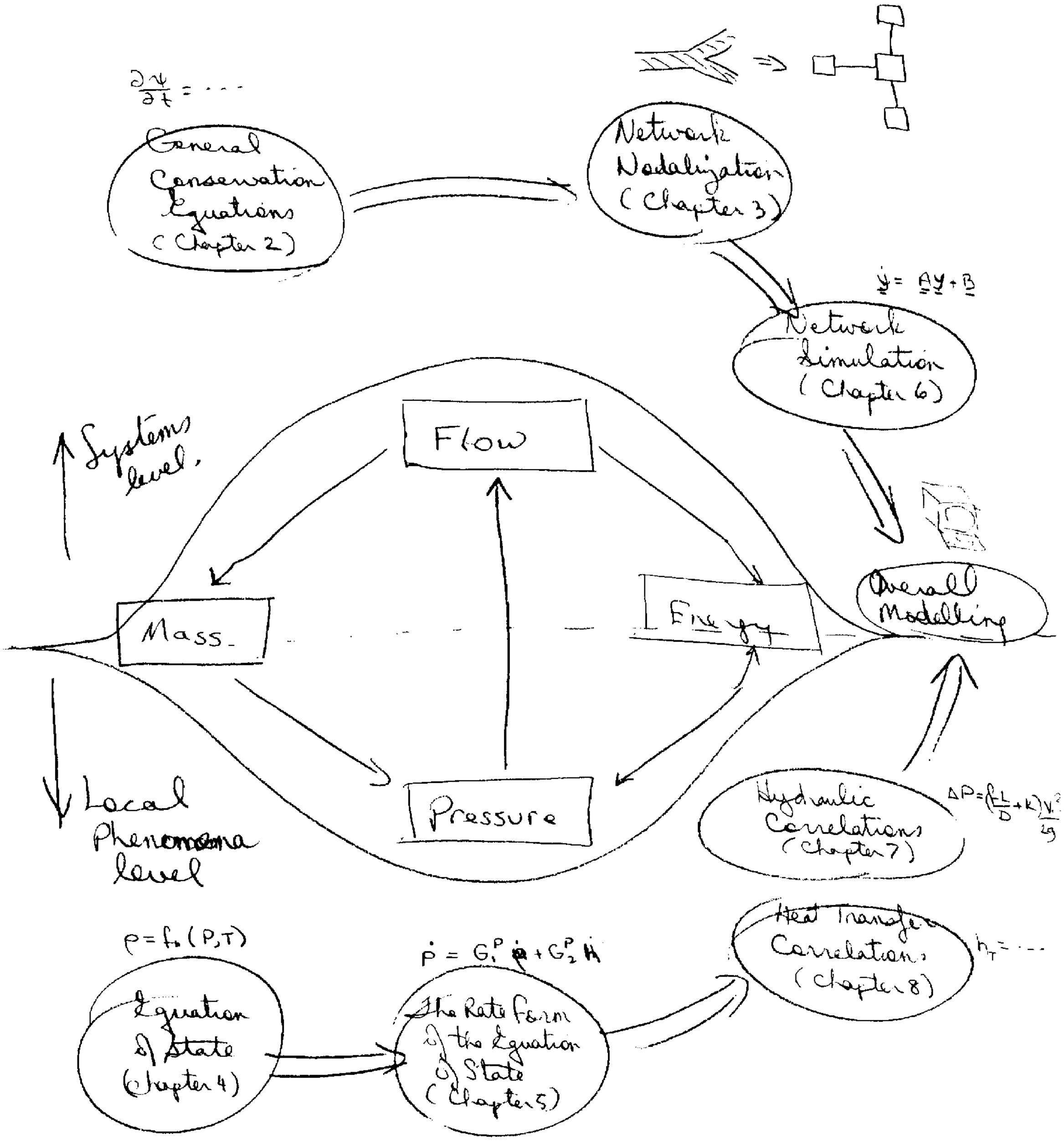

Figure 1.1 Concept map for the course

Handout Master 12.5
Objectives in the Cognitive Domain

Operationalizing the Taxonomy of Objectives in the Cognitive Domain

Taxonomic Categories and Subcategories	Verbs to Use in Objectives	Examples of Appropriate Content in Objectives
1.00 Knowledge	Define	Vocabulary words
1.1 Knowledge of specifics	Distinguish	Definitions
1.2 Knowledge of ways and means of dealing with specifics	Acquire	Facts
	Identify	Examples
	Recall	Causes
1.3 Knowledge of universals and abstractions	Recognize	Relationships
		Principles
		Theories
2.00 Comprehension	Translate	Meanings
2.1 Translation	Give in one's own words	Samples
2.2 Interpretation		Conclusions
2.3 Extrapolation	Illustrate	Consequences
	Change	Implications
	Restate	Effects
	Explain	Different Views
	Demonstrate	Definitions
	Estimate	Theories
	Conclude	Methods
3.00 Application	Apply	Principles
	Generalize	Laws
	Relate	Conclusions
	Choose	Methods
	Develop	Theories
	Organize	Abstractions
	Use	Generalizations
	Restructure	Procedures
4.00 Analysis	Categorize	Statements
4.1 Analysis of elements	Distinguish	Hypotheses
4.2 Analysis of relationships	Identify	Assumptions
4.3 Analysis of organizational principles	Recognize	Arguments
	Deduce	Themes
	Analyze	Patterns
	Compare	Biases
5.00 Synthesis	Document	Positions
5.1 Production of a unique idea	Write	Products
5.2 Production of a plan	Tell	Designs
5.3 Derivation of a set of abstract relations	Produce	Plans
	Originate	Objectives
	Modify	Solutions
	Plan	Concepts
	Develop	Hypotheses
	Formulate	Discoveries
6.00 Evaluation	Justify	Opinions
6.1 Judgments in terms of internal evidence	Judge	Accuracies
	Argue	Consistencies
6.2 Judgments in terms of external criteria	Assess	Precisions
	Decide	Courses of action
	Appraise	Standards

Adapted from N. S. Metfessel, W. Michael, and D. Kirsner. Instrumentation of Bloom's and Krathwohl's taxonomies for writing educational objectives. **Psychology in the Schools**, 1969, 6, 227–231.

Figure 1.2 The cognitive domain.