Mathematics - Course 221

INTRODUCTION

I COURSE CONTENT AND ORGANIZATION

(a) Content

This course provides an introduction to two topics:

(1) *equipment reliability evaluation*, and

(2) *calculus*.

Reliability is a specific engineering topic, whereas calculus is a basic mathematical tool. Although slightly more advanced reliability theory involves the use of calculus, as does practically every branch of science and technology, reliability and calculus appear in this course as unrelated topics.

Reliability calculations provide quantitative (ie, numerical) answers to such questions as the following:

- How reliable is this equipment?
- What is the annual risk of a reactor accident?
- How frequently should this safety system be tested?

Calculus provides the notation and techniques for solving two general classes of problems:

(1) How to find the true, or 'instantaneous' rate of change of one variable with respect to another, given the one as a function of the other (differential calculus), and:

(2) The inverse of problem (1) - How to find one variable as a function of another, given the rate of change of the one with respect to the other (integral calculus).

These techniques are applied first to the familiar quantities of velocity and acceleration, and subsequently to the time-dependent phenomena of reactor power growth, nuclear decay, water purification by ion exchange, and negative feedback in control loops.

This text makes no pretense at rigor. The least possible content and formalism have been introduced to reach the goal of treating the above applications.

(b) Organization

Six lessons reprinted from levels 4 and 3 Mathematics have been placed in front of the level 2 lessons. These six lessons provide essential background for the level 2 lessons. (Trainees will be checked out on the skills of these level 4 and 3 lessons only as these skills are involved in doing level 2 test items.) The text concludes with four appendices containing review exercises, selected AECB examination questions, methods of solving quadratic equations, and assignment answers, respectively.

II SUGGESTIONS REGARDING USE OF THIS TEXT

(1) Before becoming engrossed in the details of any lesson, scan its entire contents, paying particular attention to headings. Try to formulate a general impression of what you are expected to learn.

(2) Work through examples written into the text, referring to the text as necessary. Persist until you can work examples unaided.

(3) Do ALL assignments at the conclusions of the lessons.

(4) Practice your skills on the numerous review exercises provided in Appendix I.

III WHY CALCULUS AT LEVEL 2?

Calculus has formerly been reserved for level 1 in the NGD training program. Calculus is now being introduced at level 2, but this course is far more introductory and narrower in scope than the old level 1 course. Whereas the old level 1 course was first year university level, this course is sub-Ontario Grade 13 level.

Any discussion of training course content must be held in the light of the prevailing philosphy of training. To choose control room operator as an example of a position for which level 2 mathematics is prerequisite, two possible training philosophies are as follows:

(1) The operator needs to know nothing more than the appropriate response to each possible annunciation or sequence of annunciations, ie, he is 'programmed' to respond to every eventuality. Thus his training should consist entirely of rote memorization of procedures.

(2) Some operating procedures and emergency procedures must be learned and practised to the point where they can be performed without first having to think them through, but the operator should understand the plant systems well enough that he can make reasoned responses to such other plant situations as may arise.

Some companies lean towards philosophy (1) above, but there are problems with it. For one thing, the number of possible combinations and permutations of annunciations in a CANDU control room is so large, that to memorize detailed procedures for each one of them is impractical. Secondly, playing the role of a programmed robot could be demoralizing - people generally like to feel that they know what they are doing, and perform better when this is the case.

In any event, Ontario Hydro leans to philosphy (2). So does the AECB. Consequently, the prospective operator gets his level 2 training courses. And writes his AECB's.

Calculus provides the concepts, notation, and techniques necessary to a quantitative analysis and description of science and technology. Introductory calculus is therefore relevant background to other level 2 training, which concerns various aspects of nuclear science and technology. For example, the background knowledge of exponential and logarithmic functions, and of rates of change and integration, provided by this course, facilitates a quantitative or semi-quantitative discussion of reactor power changes and nuclear decay phenomena in the level 2 Nuclear Theory course, and of derivative and integral control in Instrumentation & Control courses.

A perusal of Appendix I confirms the relevance of 221 course content to the AECB examinations sat by operators. The point here is not that the AECB requires quantitative analyses with formal applications of calculus, but rather that the trainee is examined on subjects whose quantitative analysis certainly does involve calculus, and that the trainee with the background fundamental to understanding such subjects on the (higher) quantitative level is better able to understand and discuss them at the (lower) qualitative level. In fact, one of the best arguments for presenting calculus at level 2 is to ensure that the trainee can do it.

What of the job relevance of this course (aside from licensing requirements)? Continuing with the example of control room operator, let one concede at the outset that the operator will probably never be required to differentiate or integrate a function in the control room. Neither will he be required to recite Science Fundamentals nor even Equipment & Systems Principles. ALL of this training provides the operator with the conceptual framework and background knowledge necessary to 'evaluate the board', and make reasoned responses based on such evaluations, ie, this training is a consequence of implementing philosphy #2 on the previous page. In the parlance of the training theorist, calculus skills are "mediating skills" - skills not practised directly on the job, but facilitating job performance indirectly.

Of two people with similar native abilities examining the same control panel, the same faulty circuit, the same AECB examination, the same design manual, etc, the one with the richer web of relevant concepts and more extensive relevant knowledge in his background will, on the average, absorb what he sees faster, and analyze, apply, or synthesize the input more readily, because his brain has more reference data, more familiar stimuli with which to associate the new stimulus. In short, the richer one's relevant background, the higher is his potential job performance. Note the key word "relevant" in the foregoing - this argument cannot be used to justify NGD training courses in Babylonian architecture or ancient Near-Eastern literature, but it does vindicate introducing a control room operator, who interacts intimately with CANDU technology, to the mathematics which enables a quantitative description of that technology.

The foregoing argues generally in favour of level 2 calculus; the following are two specific examples of where Mathematics 221 content impinges on control room operation:

(a) Understanding the significance of linear power, log power, linear rate power and rate log power (cf Appendix 2), and:

(b) Interpretation of graphical representations of various physical parameters.

This brief apologetic concludes with a few comments on the following red herring: "I'll forget how to differentiate and integrate within days of writing the check-out, so why study calculus at all?" To begin with, memory-fade is a universal fact of life, true for all courses. If it were a legitimate basis for abolishing this course, it would be an equally legitimate basis for abolishing most courses. But it is not a legitimate basis for abilishing any course, because there is a useful residual to instruction/learning, which exists apart from the specific details of mathematics, history, literature, science, etc. This residual of one's general education consists of such things as the facility of critical analysis and an appreciation of the significance of the terms "objective" and "subjective". This residual remains long after the student's memory of specific details is all smudge and blur.

The useful residual of this course is envisaged to be concepts of function, rate of change (curve slope, derivative), and summation (area, integral), plus an ability to think quantitatively about time-dependent quantities, an ability which depends largely on exposure to the mathematics introduced in this text.