University of Waterloo
Department of Electrical and Computer Engineering

MATH 213, Advanced mathematics for software engineers
Spring 2013

Course Information

Themes and objectives

This course can be thought of as studying linear, time-invariant dynamic systems, from two perspectives.

In the first part of the course, we take a standard approach to the subject of differential equations. A differential equation is an equation that relates not only some variables, but derivatives of those variables with respect to an independent variable. Such equations are fundamental, and arise in a wide variety of analytical fields, from physics to engineering to economics. A solution to such an equation specifies the values of all the variables as functions of the independent variable. In general, there will be infinitely many solutions, but they can be restricted by bringing in "initial conditions," or "boundary conditions," which specify the values that the respective variables or their derivatives must take for particular values of the independent variable. The course will focus mainly on a large class of differential equations that are amenable to analytical solution – namely, linear differential equations with constant coefficients.

A dynamic system might be modelled by a differential equation, with appropriate initial conditions, that relates an input variable to an output variable. In the standard mathematical approach, the input is specified as a function of the independent variable (typically, time). The equation is then solved to yield the output signal that corresponds to that input. This traditional approach will be developed in the first part of the course, and represents a standard procedure in many application domains.

But in engineering and some other contexts, a system is conceived of as a relationship between input and output signals, and it is desirable to gain an understanding of the way a given system responds to a wide range of inputs, rather than just individual ones. The second part of the course will develop this "systems and signals" perspective. It will focus on linear, time-invariant systems, which (at least where the independent variable represents continuously varying time) are typically modelled by the same linear differential equations with constant coefficients. In this second part of the course, we will bring in the Laplace transform. While Laplace transforms can be used as a means of solving differential equations, they can also be used to define the "transfer function" of a system – an algebraic means of representing input-output relationships.

One of the particular features of linear, time-invariant systems is their response to exponential input signals: it can be found by simply multiplying the input exponential by an appropriate value of the transfer function. This is the reason for the usefulness of the Laplace transform, and it is also the reason why such systems can be studied not only in the "time domain" but in the "frequency domain." Everyday terms such as "frequency spectrum" and "bandwidth" arise directly from the frequency-domain view of linear, time-invariant systems. The frequency-domain approach motivates the use of the Fourier series and Fourier transform, two fundamental tools that decompose a signal into a sum of sinusoids, and have applications in a broad range of quantitative disciplines.

Prerequisite

MATH 119 Calculus 2 for engineering

Course instructor

J.G. Thistle Department of Electrical and Computer Engineering, EIT 3113, tel. ext. 32910, `jthistle@uwaterloo.ca`.

Teaching assistant

Nuša Zidarić `nzidaric@uwaterloo.ca`

Texts

Instructor's lecture notes on differential equations, and

Chi-Tsong Chen *Signals and Systems: A Fresh Look.*
`http://www.ece.sunysb.edu/~ctchen/media/freshlook.pdf`

Course outline

- Introduction to differential equations
  - some examples
  - ordinary differential equations and partial differential equations
  - initial conditions and boundary conditions
  - separation of variables and exactness
- Linear differential equations with constant coefficients
  - homogeneous equations and general solutions
    - the characteristic polynomial; the cases of real roots, complex roots and repeated roots
  - particular solutions
- Linear, time-invariant systems
  - linearity, time-invariance, causality, scalar vs. multivariable systems
  - the unit impulse, impulse response and convolution
  - exponentials as eigenfunctions
  - the Laplace transform and the transfer function
  - frequency response
  - the Fourier series
  - the Fourier transform

Course website

Lecture notes, assignments and assignment solutions will be posted on Learn.

Assignments

These will be assigned roughly weekly and selected problems will be discussed in tutorials. Assignments will not be handed in or graded.

Grading scheme

Final examination	70%
Midterm examination	30%

The midterm will be held on June 20, from 5:30 - 7:00 p.m. in MC 2054/2017.

Academic integrity

Naturally, academic integrity is expected in all course activities. See
`www.uwaterloo.ca/academicintegrity`
for details of University policy.