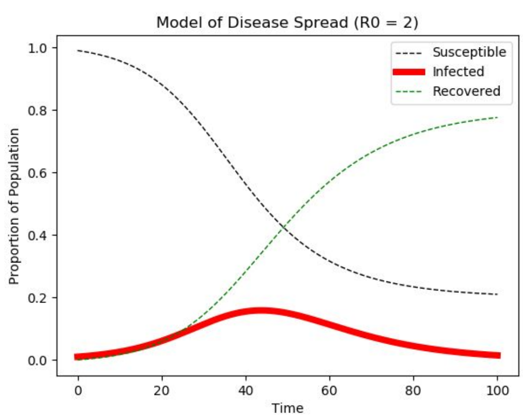
MCS 2423: Differential Equations - Dr. Johnston

Differential Equations (DEs) are widely-used across the natural sciences to model and forecast the behavior of complex systems, from the movement of the planets and moons, to the operation of electrical circuits, to forecasting the weather, to the spread of diseases (see below).

MCS 2423 is a required course for most Engineering majors as well as Mathematics and Physics majors. The course gives an introduction to the major techniques utilized in the study of first-order and second-order linear DEs, including the method of separation of variables, the method of undetermined coefficients, variation of parameters, the Laplace transform, and power series. The course relies heavily on the tools learned in the Calculus sequence (MCS 1414, 1424, and 2414) and prepares the students for MCS 3523: Mathematical Modeling, where the analysis methods for nonlinear systems are studied in more detail.



Given the wide application of DEs throughout the sciences, it is unsurprising that MCS 2423 has been offered as a CRE course in several different years and under multiple instructors. Typical offerings have allowed the students to form small groups and pick a modeling application or dataset to analyze using the tools from the class. An emphasis is placed on adhering to good modeling practice: justifying assumptions of the model, performing a pertinent test, and accurately interpreting the mathematical results in light of the original physical problem.

There are many recent project examples which have stood out as exemplary applications of DEs to real-world problems:

1. Dynamically modeling the **pollution level of Lake St. Clair** over time via an inflow-outflow model. In this application, the students researched the flow rates of rivers and streams which lead into and out of Lake St. Clair and assessed specific sources of pollution to determine how the level would rise or fall over time.
2. Modeling the **metabolism of drugs in the body** via a linear compartmental system of ordinary DEs. In this project, the students estimated the transfer rate between the GI tract and the blood serum to approximate the metabolism rate of aspirin in the body.
3. Forecasting the **spread of COVID-19** around the world via a system of nonlinear ordinary DEs. In these projects, the students used computer software such as MATLAB to compare mathematical models of the spread of COVID-19 to observed data, and then forecast how the disease might spread under a variety of scenarios such as increased/decreased social distancing or face mask utilization.