TMM024- Life Science Calculus I
(Updated 8 February 2021)

Suggested Number of Credit Hours: 4

This is the first course in a two-semester sequence of calculus courses intended for students majoring in the biological or environmental sciences and/or preparing for admission to medical, pharmaceutical, dental, veterinary, or other life-science-related professional schools. Students in this sequence must reason with limits, derivatives, integrals, and differential equations to describe and gain insight into biological processes and populations. Algebraic, logarithmic, exponential, and trigonometric functions are all used to model concepts from the life sciences. Questions from the life sciences should be used to motivate the content of the course, and the concepts and techniques taught should be used explicitly to answer those questions.

To qualify for TMM024 (Life Science Calculus I - LSCI), a course must achieve all the following essential learning outcomes listed in this document (marked with an asterisk). These make up the bulk of a Life Sciences Calculus I course. Courses that contain only the essential learning outcomes are acceptable from the TMM024 review and approval standpoint. It is up to individual institutions to determine further adaptation of additional course learning outcomes of their choice to support their students' needs. In addition, individual institutions will determine their own level of student engagement and manner of implementation. These guidelines simply seek to foster thinking in this direction. Sample tasks are listed to help clarify the intention of the essential learning outcomes, but no specific sample task is required for approval. Institutions are encouraged to tailor specific applications to the population of life science students at their institution.

In a Life Science Calculus I (TMM024) course, students should:

- develop effective thinking and communication skills;
- operate at a high level of detail;
- state problems carefully, articulate assumptions, understand the importance of precise definition, and reason logically to conclusions;
- identify and model essential features of a complex situation, modify models as necessary for tractability, and draw useful conclusions;
- deduce general principles from particular instances;
- use and compare analytical, visual, and numerical perspectives in exploring mathematics;
- assess the correctness of solutions, create and explore examples, carry out mathematical experiments, and devise and test conjectures;
- recognize and make mathematically rigorous arguments;
- read mathematics with understanding;
- communicate mathematical ideas clearly and coherently both verbally and in writing to audiences of varying mathematical sophistication;
- approach mathematical problems with curiosity and creativity, persist in the face of difficulties, and work creatively and self-sufficiently with mathematics;
- learn to link applications and theory;
- learn to use technological tools; and
- develop mathematical independence and experience open-ended inquiry.

– Adapted from the MAA/CUPM 2015 Curriculum Guide

1. **Modeling with Elementary Functions:** Successful LSCI students have a deeper understanding of elementary functions beyond what is learned in prerequisite courses. They will communicate and interpret information about functions given algebraically, graphically, numerically, and verbally. Students will appreciate linear, exponential, logarithmic, and logistic functions as tools to model phenomena in applications. A key concept is that linear functions are those functions with constant rates of change, and that exponential growth and decay is an appropriate model when a constant percentage rate of change occurs. (Trigonometric functions are contained in Life Science Calculus II).

   The successful LSCI student can:

   1.1. Construct a linear model from given linear data. Interpret the slope of a linear model as a constant rate of change. Recognize a situation with constant rate of change as appropriate for a linear model.*

   1.2. Use exponential functions to model growth and decay with constant percentage change. Compute the half-life or doubling time of an exponentially-modelled quantity. Examples include population growth and drug concentration. *

   1.3. Use logistic functions to model natural phenomena such as bounded population growth. Identify the horizontal asymptotes and point of steepest increase/decrease. *

   1.4. Interpret and generate logarithmic scale graphs. Use logarithmic scale graphs to distinguish different types of growth. *

2. **Limits and Continuity:** Successful Calculus students demonstrate understanding of the concepts of limit and continuity whether described verbally, numerically, graphically, or algebraically (both explicitly and implicitly).

   The successful LSCI student can:

   2.1. Evaluate limits using tables of function values. This includes one- and two-sided limits at a point as well as limits at infinity and infinite limits. *

   2.2. Evaluate limits using a graph of a function. This includes one- and two-sided limits at a point as well as limits at infinity and infinite limits. *

   2.3. Use the limit to describe graphical attributes of a function and interpret the meaning of these attributes in a given life science context. *

   Sample Task:

   - Use asymptotic functions to model quantities that are approaching some theoretical limit, such as a population carrying capacity or the amount of a drug in the bloodstream.

   2.4. Evaluate limits algebraically using limit laws. *

   2.5. Determine continuity of a simple function from its graph. *

   2.6. Use the definition of continuity to determine whether a given function is continuous. *

3. **Rate of Change:** Successful LSCI students have a robust understanding of the concept of rate of change and how it relates to slope on a graph, and the increase or decrease of a quantity in context. They can explain this concept verbally and graphically as well as recognize that derivatives are rates of change.

   The successful LSCI student can:

   3.1. Interpret the slope of a secant line as an average rate of change of a quantity using correct units. *

   3.2. Relate average rate of change over an interval to instantaneous rate of change at a point. Decide if a given graph shows a tangent line or a secant line. *

   3.3. Estimate instantaneous rate of change from a graph using a tangent line. *

   3.4. Interpret the slope of a tangent line as instantaneous rate of change of a quantity, using correct units. *

4. **Differentiation:** Successful LSCI students are able to compute derivatives and interpret them as rates of change. They can use the formal limit definition of derivative to compute simple derivatives and explain where this limit definition comes from. They can also use product, quotient, and chain rules to compute more complicated derivatives and decide when to use these rules when given a contextual rate-of-change problem.

   The successful LSCI student can:

   4.1. Find the derivative of a function using the limit definition of derivative. This computation can be performed numerically (with tables) and algebraically. *

   4.2. Compute derivatives of elementary algebraic and transcendental functions using the power rule, product rule, quotient rule, and chain rule. *

   4.3. Interpret the value of a derivative as a rate of change with units. *

   4.4. Determine where a derivative does not exist, using a function’s formula or its graph. *

   4.5. Compute higher-order derivatives e.g. second derivatives. *

5. **Applications of Derivatives:** Successful LSCI students can use derivatives to solve optimization problems, to describe graphs, and to explain natural phenomena (such as velocity and acceleration).

   The successful LSCI student can:

   5.1. Use the first and second derivative of a function to gather information about the function, including: intervals of increase/decrease, critical points, relative and absolute extrema, concavity, and inflection points. *

   Sample Task:

- Find the inflection point of a given breast cancer tumor growth function and describe its significance.

5.2. Solve optimization problems in the life science context using first and second derivatives. *

Sample Task:

- Find the maximum and minimum of the therapeutic window of a drug

6. **Integration:** Successful LSCI students are familiar with definite and indefinite integrals. Deeper understanding of integration may be gained in Life Sciences Calculus II.

The successful LSCI student can:

6.1. Use Riemann sums to estimate definite integrals. *
6.2. Evaluate definite integrals using the Fundamental Theorem of Calculus. *
6.3. Evaluate indefinite integrals using basic antiderivative formulas e.g. power rule. *
6.4. Answer questions motivated by the life sciences by computing areas under graphs. *

Sample Task:

- Analyze pathogenesis curves of diseases.

6.5. Interpret the meaning of a definite integral of a function in terms of areas of regions between the graph of the function and the x-axis. *

Sample Tasks:

- The student explains the conditions under which the definite integral of a function gives the area between that function and the x-axis, and the precautions that must be taken when using definite integrals to calculate area.
- Given the graph of a function and the area of each region enclosed by the graph and the x-axis, the student finds the value of a given definite integral of that function.

6.6. Find indefinite and definite integrals using the method of substitution. *

Sample Tasks:

- Given an integral, the student identifies substitution as an appropriate technique.
- The student chooses an optimal expression to convert to a new variable and restates the integral in terms of that new variable.
- The student converts any integration limits to the new variable.
- The student evaluates the transformed integral and recovers the format of the original function.
- The student solves life science application problems that require the method of substitution.