

MATH 102 - Differential Calculus with Applications to Life Sciences - course outline (hardcopy summary)

From UBCMATH WIKI

2015W Term 1, September-December 2015

Course overview

As with any course on differential calculus, the central character in this course is the derivative. The course starts by building up to the limit definition of the derivative and proceeds through analytical, graphical and numerical approaches to build students' understanding of several types of functions and their derivatives. Next, we cover optimization, with applications to biological systems as well as principles of data fitting. A section on growth, decay and periodic phenomena precedes an introduction to differential equations and their use in modeling of biological systems.

One big difference between this course and a more traditional calculus course is the inclusion of examples and applications from the life sciences in place of the more traditional emphasis on physics. These examples and applications come from a wide range of fields including biochemistry, cell biology, ecology, genetics, population biology and evolution.

Course policies

Prerequisites

See the UBC Calendar entry for Math 102 (<http://www.calendar.ubc.ca/vancouver/courses.cfm?code=MATH#102>) for course prerequisites. If you do not satisfy the course prerequisites, you may find yourself automatically de-registered from the course once the term begins. The fact that you were able to register does not mean you satisfy the prerequisites.

Marking scheme

- Final exam 50%
- Midterm 15%
- Online WeBWorK homework 15%
- Quizzes 15%
- Written assignments (OSH) 5%

WeBWorK points and the 5% rule: Each problem submitted to WeBWorK is given a point-weight and your total WebWork score will be counted out of 95% of the total number of WeBWork points. Thus, if there are a total of 400 WeBWork points this term, you can get 20 points worths of them wrong and still get the full 15% allocated to WeBWork problems. This is not intended as a point give-away. It is intended to account for the fact that, early in the semester, you will take some time to master using WeBWorK and we do not have the resources to evaluate every request for accommodation for every technical glitch you run into. Any requests for accommodation regarding WeBWorK points due to alleged WeBWorK glitches, computer crashes etc. are by default covered by the 5% rule.

For more information on WeBWorK and OSH assignments, see the Assignments page.

A minimum mark of 44% on the final exam is required to pass the course, independent of all others marks in the course.

Independent work

You are encouraged to work in groups on homework assignments although independent effort is also crucial to learning. However, any misrepresentation of another person's work as your own is considered to be academic dishonesty. In particular, directly copying someone else's homework will be treated as a violation of UBC's Academic Integrity Code. See the UBC regulations of plagiarism (<http://vpacademic.ubc.ca/integrity/ubc-regulation-on-plagiarism/>) for details.

Midterm absences, late or non-existent homework

If you are unable to attend the midterm, you must notify your instructor beforehand (preferred) or within two days after (in the case of emergencies) the exam date. In either of these two cases (and only in these two cases), suitable accommodations will be made. Undocumented absence from the midterm will be given a score of zero.

If you have a course or another midterm that conflicts with the midterm time, notify your instructor **no later than Sept 30**.

No midterm rewrites will be granted.

No late homework will be accepted.

Final exam regulations

For a full description of the final exam regulations, see the UBC Calendar page on Student Conduct during Examinations (<http://www.calendar.ubc.ca/vancouver/index.cfm?tree=3,41,90,0>). In particular, notes, calculators, cell phones and other electronic devices are strictly prohibited from use during the exam. This includes use of cell phones for checking the time. The same regulations apply for the midterm.

Registration

Add/drop forms must be brought to the math department office. An instructor's signature is neither sufficient nor necessary on an add/drop form. See the Mathematics Department registration information page (<http://www.math.ubc.ca/Ugrad/ugradRegistration.shtml>) for more information.

Re-marking requests

If you feel that a returned homework assignment or midterm is incorrectly marked, you can appeal that mark by writing a note that details your concern, attaching it to the assignment, and resubmitting it to the instructor within one week of the return of the marked assignment. The note should include a summary of what you feel was incorrectly evaluated with some justification of the claim.

Course calendar

WeBWorK, OSH due dates and quizzes in Month View:

- MWF sections
- TTh sections

| | Date | What's due | Lecture topic | Course notes | Videos |
|--------|--------|------------|---|--|------------|
| Week 1 | Sep 9 | | Cell size: volume, area. Power functions. | Sec 1.1-1.2 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap1.pdf) | video link |
| | Sep 11 | | Power functions (cont). Sketching simple polynomials ($y=x^3-ax$). | Sec 1.1, 1.4, 1.6 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap1.pdf) | video link |
| Week 2 | Sep 14 | | Sketching simple polynomials (cont). Rational functions, Michaelis-Menten and Hill functions, "limits" at infinity. | Sec 1.4, 1.5 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap1.pdf) | video link |
| | Sep 16 | | Average rate of change and secant lines. Definition of the derivative. Instantaneous rate of change. | Sec 2.2-2.5 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap2.pdf) | video link |

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| | Sep 17 | WW 1 | | | |
| | Sep 18 | OSH 1 | Limits and continuity, examples. One example of computing derivative of $y = ct^2$ from the definition. | Sec 2.5 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap2.pdf) , 3.2 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap3.pdf) , Appendix D (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102Endmatter.pdf) . | video link |
| Week 3 | Sep 21 | | Derivatives: analytic, and geometric (zoom in on a point). Sketching $f'(x)$ given $f(x)$ (intro). | Sec 3.1-3.2 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap3.pdf) | video link |
| | Sep 23 | | Derivatives (cont): computational (spreadsheet example in class). More examples of sketching $f'(x)$ given $f(x)$ (intro). | Sec 3.2-3.3 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap3.pdf) | video link |
| | Sep 24 | WW 2 | | | |
| | Sep 25 | Quiz 1 | Rules of differentiation: Product and quotient rules. Antiderivatives of power functions. Application to falling ball, motion of Listeria. Sketching $f(x)$ given $f'(x)$ (intro using polynomial). | Chap 4 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap4.pdf) | video link |
| Week 4 | Sep 28 | | Tangent lines. | Sec 5.1-5.3 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap5.pdf) | video link |
| | Sep 30 | | Linear approximation. Newton's method. | Sec 5.4 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap5.pdf) , 6.1 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap6.pdf) | video link |
| | Oct 1 | WW 3 | | | |
| | Oct 2 | OSH 2 | Sketching the graph of a function using calculus tools (cont): increasing, decreasing, critical points, concavity and inflection points. | Sec 6.1-6.3 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap6.pdf) | video link |
| Week 5 | Oct 5 | | Putting it all together - sketching. | | video link |
| | Oct 7 | | Finish sketching functions. | Sec 6.3-6.4 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap6.pdf) , | video link |

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| | | Introduce simple optimization problem(s). | 7.1 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap7.pdf) | |
| Oct | WW 4 | | | |
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| Oct | Quiz 2 | More optimization examples including those with a constraint and those on bounded intervals. Distinction between absolute (global) and local minima and maxima. | Sec 7.1-7.3 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap7.pdf) | video link |
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| Week | Oct | THANKSGIVING | | |
| 6 | 12 | - no classes. | | |
| | Oct | Kepler's Wedding - A wine optimization problem. | Sec 7.2 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap7.pdf) | video link |
| | 14 | | | |
| | Oct | WW 5 | | |
| | 15 | | | |
| Oct | OSH 3 | Optimal Foraging. | Sec 7.4 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap7.pdf) | video link |
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| Week | Oct | Least Squares - finding the mean of a data set. | Supplement | video link |
| 7 | 19 | | | |
| | Oct | MIDTERM: sign up for a time on Connect | | |
| | 20 | | | |
| | Oct | Least Squares - finding the best fitting line $y = ax$ through a set of data points. | Supplement | video link |
| | 21 | | | |
| | Oct | WW 6 | | |
| | 22 | | | |
| Oct | | Chain Rule: examples, applications to optimization problems. | Chap 8 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap8.pdf) | video link |
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| Week | Oct | More Chain Rule: Related Rates and Implicit differentiation. | Chap 9 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap9.pdf) | video link |
| 8 | 26 | | | |
| | Oct | Exponential functions: intro and motivation, derivative of | Sec 10.1-10.2 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap10.pdf) | video link |
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| | | exponential functions. | | |
| | Oct 29 | WW 7 | | |
| | Oct 30 | OSH 4 | Inverse functions and logarithm, applications of logs. | Sec 10.3-10.4 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap10.pdf) video link |
| Week 9 | Nov 2 | | Exponential growth and decay, intro to differential equations, population growth and/or other examples. | Sec 11.1; 11.2 or 11.3 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap11.pdf) video link |
| | Nov 4 | | Solving differential equations of the type $dy/dt = a - by$. | Sec 12.1-12.3 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap12.pdf) video link |
| | Nov 5 | WW 8 | | |
| | Nov 6 | Quiz 3 | Newton's Law of Cooling (Murder Mystery example). | Sec 12.4 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap12.pdf) video link |
| Week 10 | Nov 9 | | Complete and/or review above topics. | Chaps 11-12 video link |
| | Nov 11 | | Remembrance Day. University closed. ***Push topics back... Solving differential equations approximately using Euler's Method. | Sec 12.4 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap12.pdf) video link |
| | Nov 12 | WW 9 | | |
| | Nov 13 | OSH 5 | Go over midterm. Introduction to nonlinear ODEs, qualitative analysis. | Sec 13.1 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap13.pdf) video link |
| Week 11 | Nov 16 | | Slope fields with logistic equation as example. | Sec 13.2 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap13.pdf) video link |
| | Nov 18 | | State-space diagrams and examples (logistic). | Sec 13.2 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap13.pdf) video link |
| | Nov 19 | WW 10 | | |
| | Nov 20 | Quiz 4 | Disease dynamics. | Sec 13.3 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap13.pdf) video link |

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| Week 12 | Nov 23 | Review of differential equations and/or complete above topics. | Chaps 11-13 | video link | |
| | Nov 25 | Introduction to Trigonometric Functions. | Sec 14.1-14.2 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap14.pdf) | video link | |
| | Nov 26 | WW 11 | | | |
| | Nov 27 | OSH 6 | Trigonometric Functions and cyclic processes, phase, amplitude, etc. (fitting a sin or cos to a cyclic process), Inverse trig functions. | Sec 14.2-14.3 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap14.pdf) | video link |
| Week 13 | Nov 30 | Derivatives of trig functions, related rates examples. | Sec 15.1-15.2 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap15.pdf) | video link | |
| | Dec 2 | The Escape Response and inverse trig functions. | Sec 15.3 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap15.pdf) | video link | |
| | Dec 3 | WW 12 | | | |
| | Dec 4 | Quiz 5 | Second order ODEs. Complete and/or review trig. | Sec 15.4 (http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap15.pdf) | video link |

Course notes

These course notes were written and have been provided voluntarily for many years by Prof. Leah Keshet (UBC Math). They have been based on material she developed and taught in Math 102.

You can optionally get a full printed copy of the notes at [1] (<http://www.copiesmart.com/>) Copiesmart (5728 University Blvd #103, Vancouver, BC V6T 1K6).

Or: download the Full version (see below), which has internal links from the table of contents and index.

They are being updated over time. These notes are provided for all interested in learning. Copyrights are reserved by Keshet. Last update: September, 2015. (A list of known errors appears below)

The latest version of the Math 102 course Notes:

- Chapter 1 (<http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap1.pdf>) : Power functions as building blocks
- Chapter 2 (<http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap2.pdf>) : Average rates of change, average velocity and the secant line
- Chapter 3 (<http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap3.pdf>) : Three faces of the derivative: geometric, analytic, and computational
- Chapter 4 (<http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap4.pdf>) : Differentiation rules, simple antiderivatives and applications
- Chapter 5 (<http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap5.pdf>) : Tangent lines, linear approximation, and Newton's method

- Chapter 6 (<http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap6.pdf>) : Sketching the graph of a function using calculus tools
- Chapter 7 (<http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap7.pdf>) : Optimization
- Chapter 8 (<http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap8.pdf>) : Introducing the chain rule
- Chapter 9 (<http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap9.pdf>) : Chain rule applied to related rates and implicit differentiation
- Chapter 10 (<http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap10.pdf>) : Exponential functions
- Chapter 11 (<http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap11.pdf>) : Differential equations for exponential growth and decay
- Chapter 12 (<http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap12.pdf>) : Solving differential equations
- Chapter 13 (<http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap13.pdf>) : Qualitative methods for differential equations
- Chapter 14 (<http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap14.pdf>) : Periodic and trigonometric functions
- Chapter 15 (<http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102chap15.pdf>) : Cycles, periods, and rates of change
- Review Problems, Appendices, Table of Contents, Answers and Index (<http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102Endmatter.pdf>)

The Full version (below) has embedded html links. Download that version to your laptop or ipad to have full capability of the internal links.

- Full pdf version (<http://www.math.ubc.ca/~keshet/M102/M102CourseNotes/M102NotesSept2015.pdf>) with internal links

Known errors in Course Notes

- Chap 2: Defn 2.13: should be $(\text{change in } y)/(\text{change in } x)$

Supplements

- Earth's energy balance
- Fitting data - least squares
- Optimal foraging
- Numerical integration
- Degrees or radians - why you should always use radians

Hard copies

You can buy a printed paper copy of this material from Copiesmart (<http://copiesmart.com/>) on University Boulevard.

Address: Copiesmart, #103 5728 University Blvd. Tel: 604-222-3189, 604-222-3194.

Additional references

- Stewart's *Calculus: Early Transcendentals* is available at the UBC bookstore and can be found secondhand as it is used for a number of other first year calculus courses on campus. It does not cover all the topics we cover in this course and covers some topics we do not cover but there is a significant overlap and, for some topics, especially the basic ones, you might find useful worked examples.
- Paul's online notes (<http://tutorial.math.lamar.edu/Classes/CalcI/CalcI.aspx>) , written by Prof. Paul Dawkins (<http://www.math.lamar.edu/faculty/dawkins/dawkins.aspx>) at Lamar University (<http://www.lamar.edu/>) provides a good, free and online resource for a standard calculus course.

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