# PHYS 3201: Mathematical Methods in Physics II (winter)

*Calendar description:* This course is a continuation of PHYS 3200.1(.2) and covers additional topics in mathematical physics, including special functions (Bessel, Neumann, Lagrange, etc.), Green's functions, Fourier series and transforms, Laplace transforms, integro-differential equations, and Hilbert-Schmidt theory.

Note: Credit cannot be given to students who already have a credit for MATH 3406.1(.2) and/or MATH 4437.1(.2).

Contents


Overview . . . 1
Prerequisites . . . 2
Dependent courses . . . 2
Student outcomes . . . 3
Curriculum . . . 3
Suggested Texts . . . 4
Notes to the Instructor . . . 4


## Overview

The "Methods (200) Stream" is specifically designed to provide the mathematics and computing skills needed in concurrent and subsequent physics courses. The 200-stream courses are not intended to teach mathematics and computing for their own sakes, but for the purpose of relieving the instructors of the physics courses from having to teach mathematics in support of their curriculum. Thus, the curriculum of the 200-stream courses should be sensitive and altered to suit the mathematical and computational needs of the dependent physics courses.

The two mathematical methods courses (this course and its prerequisite PHYS 3200) are part of the programme because:

1. the material they contain cannot be found in any one, and often any two MATH courses; and

2. the math department doesn't cover the needed material in time for when the physics courses are taught.

That said, students in the MATH/PHYS double major/honours programmes take MATH courses instead of the math methods courses.

The "equivalent" MATH courses to this course are MATH 4405/4406 and either MATH 3456/3457 or MATH 4436/4437. Together, these courses cover about 75% of what is covered in this course and PHYS 3200.

## Prerequisites

PHYS 3200 Mathematical Methods in Physics I

This course is a continuation of PHYS 3200, and mastery of many ideas covered there is assumed. Students should be able to solve any ordinary second order differential equation, and be comfortable with Cauchy integration.

## Dependent courses

PHYS 3400 Electrodynamics

PHYS 3400 is cycled with PHYS 3350 (Thermal Physics). When taught in the fourth year, all the mathematics from PHYS 3201 can be used by PHYS 3400, but when taught in the third year, PHYS 3400 and PHYS 3201 are concurrent and thus this course cannot be listed as a prerequisite for PHYS 3400 (though ideally it would be). Thus, the instructors of PHYS 3201 and 3400 should coordinate their topics so that the math taught in this course can be useful for the third year students in PHYS 3400. A prime example of this is the discussion on integro-differential equations which may be needed in Electrodynamics sooner than listed in the suggested curriculum (below) for this course.

PHYS 4380 Fluid Dynamics

This course benefits from the mathematical sophistication derived from PHYS 3201, more than the specific topics taught.

PHYS 4390 General Relativity

This course also benefits from the mathematical sophistication obtained from PHYS 3201, and will then introduce its own topics in mathematics (e.g., Tensors, p-forms, etc.) to pursue Einstein's equations. At this time, it is suggested that tensor theory *not* be covered in any of the courses in the 200 (methods) series.

PHYS 4500 Quantum Mechanics II

This course depends heavily on the Dirac notation introduced in MASTH 2301 (Linear Algebra) and reinforced elsewhere, Green's functions and Sturm-Liouville (operator) theory discussed in PHYS 3200, special functions and, to a lesser extent, Hilbert-Schmidt

theory covered in PHYS 3201.

PHYS 4501 Quantum Mechanics III (indirectly)

See discussions under PHYS 4500.

PHYS 4510 Subatomic Physics (indirectly)

See discussions under PHYS 4500.

## Student Outcomes

Students completing PHYS 3201 should have mastered the following skills:

1. Pose and analyse a physical problem mathematically without undue hindrance from a lack of appropriate mathematical skills;
2. Prepare and present a mathematical physics problem in a coherent fashion, easily understood by another student.
3. Solve problems and display results with commonly available computational packages such as Maple, IDL, etc.

## Curriculum

1. special functions
   - Gamma-Factorial Functions
   - Bessel, Neumann, Hankel functions
   - Lagrange, Laguerre, Chebyschev polynomials.
   - graphical behaviour and asymptotical limits
2. Fourier series
   - DFTs, FFTs
3. integral transforms
   - Fourier transforms/convolutions
   - Laplace/inverse Laplace transforms
   - Faltungs Theorem
4. integro-differential equations
   - Neumann series
   - Hilbert-Schmidt theory
5. Chaos (optional)
   - non-linear differential equations

## Suggested texts

*Mathematical Methods for Physicists* by Arfken (ISBN 0-12-059826-4)

- has all the material required at an appropriate level for third year students, and can be used for PHYS 3200 as well.
- acknowledged by most professors as the best text available for Mathematical Physics

*Mathematical Methods of Physics* by Mathews and Walker (ISBN 0-8053-7002-1)

- while used at some institutions for an undergraduate course, this text is widely acknowledged as a graduate text on the subject.
- Much denser than Arfken.

*Mathematical Physics* by Butkov (ISBN 0-201-00724-4)

- a viable alternate to Arfken, though much drier and considerably denser.

## Notes to the instructor

1. PHYS 3201 is taken concurrently with either PHYS 3350 (Thermal Physics) or PHYS 3400 (Electrodynamics), these two courses being cycled between the second semesters of third and fourth year. The instructor of PHYS 3201 should be in communication with the instructors of these courses, particularly Electrodynamics, to be certain to cover the material in a sequence most beneficial to them. For example, it may be necessary to teach the unit on integro-differential equations sooner, depending on when these are encountered in PHYS 3400.
2. This course is the only place where students will see topics such as integral transforms and integro-differential equations (*e.g.*, the Boltzmann equation) covered.
3. There is no reason not to use the same text for PHYS 3200 and PHYS 3201, and the two instructors of these courses should agree on a common text.