

# Physical Applications of Fourier Analysis

PHYS 4203/5313

**Course Instructor:** Tong Xu

**Office Location:** Room 3318, Herzberg Building

**How to address me:** Tong

**Gender Pronouns:** (he/him/his) ([learn more](#))

**Class Location:** Posted on Carleton Central

**Email:** txu@physics.carleton.ca

**Class Times:** Monday & Wednesday, 11:35am-12:55pm

Note: If you have a question or would like to talk with me, you can send an email, visit me during student hours (see below), or approach me after lecture.

**Prerequisites:** MATH 3705, or permission of the Department.

**Phone:** (613) 520-2600x8794

Student Hours: TBD.

## What are 'Student Hours'?

Student hours are dedicated times through the week for the course instructor and TAs to meet with YOU. Pop in to introduce yourself, ask questions about the course, or discuss content from the course.

Note: If these times don't work for you, email me and we can arrange an alternate time to meet.

## Course level learning objectives:

1. students will have mastery of the mathematics of convolution, Fourier analysis, and their application to linear systems in one dimension and in two and three dimensions.
2. students will visualize signal analysis problems in both the normal domain (time or space) and the reciprocal domain (time frequency or spatial frequency).
3. students will be able to define and analyse multistep analytic problems in signal analysis, including in imaging, using Fourier transform tools and using tools from prior courses in calculus and algebra, and will be able to document their analysis for others.
4. students will have an understanding of the Discrete Fourier Transform and of algorithms for its calculation.
5. at an introductory level, students will understand and be able to apply the mathematical bases of image reconstruction in CT and MRI.
6. (if time permit) students will have a sense of the history of the field, having been introduced to Joseph Fourier and to other mathematicians and physicists

## Course content

- Review Heat Equation and Fourier series
- Fourier transform
- Convolution and correlation
- Examples of transforms
- Analysis of linear systems, filtering, and noise
- Sampling theorem and aliasing
- Discrete Fourier Transform (DFT)
- Fast Fourier Transform (FFT)
- Two-dimensional Fourier transform
- Resolution descriptors in imaging
- Image reconstruction from projections - computed tomography (CT)
- Principles of MRI
- Fraunhofer diffraction
- Other related transforms (if time permit)

Please feel free to contact me via email or in person to let me know about any experiences you have had related to this class that have made you feel uncomfortable.

## Land Acknowledgement

Here at Carleton University, it is important that we acknowledge that the land on which we gather is the traditional and unceded territory of the Algonquin nation.

## Community Guidelines

The following values are fundamental to academic integrity and are adapted from the International Center for Academic Integrity\*. In our course, we will seek to behave with these values in mind:

	As students, we will...	As a teaching team, we will...
<b>Honesty</b>	<ul style="list-style-type: none"> <li>• Honestly demonstrate our knowledge and abilities on assignments and exams</li> <li>• Communicate openly without using deception, including citing appropriate sources</li> </ul>	<ul style="list-style-type: none"> <li>• Give you honest feedback on your demonstration of knowledge and abilities on assignments and exams</li> <li>• Communicate openly and honestly about the expectations and standards of the course through the syllabus, and with respect to assignments and exams</li> </ul>

<b>Responsibility</b>	<ul style="list-style-type: none"> <li>• Complete assignments on time and in full preparation for class</li> <li>• Show up to class on time, and be mentally/physically present</li> <li>• Participate fully and contribute to team learning and activities</li> </ul>	<ul style="list-style-type: none"> <li>• Give you timely feedback on your assignments and exams</li> <li>• Show up to class on time, and be mentally &amp; physically present</li> <li>• Create relevant assessments and class activities</li> </ul>
<b>Respect</b>	<ul style="list-style-type: none"> <li>• Speak openly with one another, while respecting diverse viewpoints and perspectives</li> <li>• Provide sufficient space for others to voice their ideas</li> </ul>	<ul style="list-style-type: none"> <li>• Respect your perspectives even while we challenge you to think more deeply and critically</li> <li>• Help facilitate respectful exchange of ideas</li> </ul>
<b>Fairness</b>	<ul style="list-style-type: none"> <li>• Contribute fully and equally to collaborative work, so that we are not freeloading off of others</li> <li>• Not seek unfair advantage over fellow students in the course</li> </ul>	<ul style="list-style-type: none"> <li>• Create fair assignments and exams, and grade them in a fair, and timely manner</li> <li>• Treat all students equitably</li> </ul>
<b>Trust</b>	<ul style="list-style-type: none"> <li>• Not engage in personal affairs while on class time</li> <li>• Be open and transparent about what we are doing in class</li> <li>• Not distribute course materials to others without authorization</li> </ul>	<ul style="list-style-type: none"> <li>• Be available to all students when we say we will be</li> <li>• Follow through on our promises</li> <li>• Not modify the expectations or standards without communicating with everyone in the course</li> </ul>
<b>Courage</b>	<ul style="list-style-type: none"> <li>• Say or do something when we see actions that undermine any of the above values</li> <li>• Accept a lower or failing grade or other consequences of upholding and protecting the above values</li> </ul>	<ul style="list-style-type: none"> <li>• Say or do something when we see actions that undermine any of the above values</li> <li>• Accept the consequences (e.g., lower teaching evaluations) of upholding and protecting the above values</li> </ul>

<sup>2</sup> This class statement of values is adapted from Tricia Bertram Gallant, Ph.D.

## Learning Materials

### Textbook:

R. N. Bracewell, The Fourier Transform and its Applications, McGraw-Hill [The book is out of print. It's best to get a used copy. One can also download a pdf from the internet.]

### Other references:

J.F. James “A Student's Guide to Fourier Transforms: With Applications in Physics and Engineering”, Cambridge University Press; 3 edition, 2011 ([E-book, free access for students from Carleton Library website](#))

Robert J. Marks II “Handbook of Fourier Analysis & Its Applications”, Oxford University Press, 2009

## Assessments

There are **11 assignments**, with one assignment due almost every week. **Top 9 assignments** will be used for your assignment mark in the course. Clarity, rigour, and organization are important parts of your solutions. The due dates of the assignments are:

Assignments	Due dates	Assignments	Due dates
#1	Sept 12	#6	Oct 24
#2	Sept 19	#7	Oct 31
#3	Sept 26	#8	Nov 7
#4	Oct 3	#9	Nov 14
#5	Oct 10	#10	Nov 28
Mid-term exam Oct 16		#11	Dec 4

## Project (PHYS 5313 students only)

Each student in Phys 5313 will write a report (max 15 pages, graph and bibliography included) and make a class presentation (~20 min + questions) on an application of Fourier analysis of their choice. Some examples: x-ray diffraction, voice recognition, hearing aid signal processing, optical Fourier transform. You may propose your own topic. Each student’s topic must be unique in the class. The goal of the presentation is to introduce the basic concept of the application. Balance general intro, theory, and application so that others can learn from you. You may use Powerpoint, Adobe, or other compatible software. The presentations will be during the last week of term. Please discuss your choice of topic with the instructor no later than Oct 22.

## Exams

Both midterm and final exam will be in-person.

The midterm exam (75 min) will take place on **Oct 16<sup>th</sup>** during the lecture time.

The final exam (180 min) will take place during the final exam period.

## Grade Breakdown

COMPONENT	GRADE VALUE	GRADE VALUE
	PHYS 4203	PHYS 5313
ASSIGNMENTS	45%	40%
MIDTERM	20%	20%
FINAL EXAM	35%	30%
PROJECT	N/A	10%

## Copyright

Classroom teaching and learning activities, including lectures, discussions, presentations, etc., by the instructor and by students, are copy protected and remain the intellectual property of their respective author(s). All Phys 4203 and Phys 5313 course materials, including PowerPoint and pdf files and other materials, are also protected by copyright and remain the intellectual property of their respective author(s).

Students registered in the course may take notes and make copies of course materials for their own educational use only. You may not allow others to reproduce or distribute course materials. Students are not permitted to reproduce or distribute lecture recordings or other course materials publicly for commercial or non-commercial purposes.

## Mental Health

If you are struggling, please do not hesitate to reach out. I am happy to listen, and/or direct you to resources that might help. In terms of class, if you need extra help or missed a lesson, don't stress! Email me and we will set a time to meet. I'll work with you, I promise. Remember that Carleton also offers an array of mental health and well-being resources, which can be found [here](#).

## University Policies

In accordance with the Carleton University Undergraduate Calendar Regulations, the letter grades assigned in this course will have the following percentage equivalents:

A+ = 90-100	B+ = 77-79	C+ = 67-69	D+ = 57-59
A = 85-89	B = 73-76	C = 63-66	D = 53-56
A- = 80-84	B- = 70-72	C- = 60-62	D- = 50-52
F = <50			
WDN = Withdrawn from the course			
DEF = Deferred			

## Academic Accommodations, Regulations, Plagiarism, Etc.

Carleton is committed to providing academic accessibility for all individuals. You may need special arrangements to meet your academic obligations during the term. The accommodation request processes are outlined on the Academic Accommodations website ([students.carleton.ca/course-outline](https://students.carleton.ca/course-outline))

- **Deferred/missed term work for short-term accommodation (5 days or less):**  
Short term accommodation may be requested by email with legitimate reasons.
- **Deferred/missed term work for longer term incapacitation (5 days or longer);**  
If you require accommodations for this course that are longer than the 5-day (short-term) period, please email me to discuss how/whether accommodation needs could be met for this course.

## Academic Integrity

Academic Integrity is upholding the values of honesty, trust, respect, fairness, responsibility, and courage that are fundamental to the educational experience. Carleton University provides supports such as academic integrity workshops to ensure, as far as possible, that all students understand the norms and standards of academic integrity that we expect you to uphold. Your teaching team has a responsibility to ensure that their application of the Academic Integrity Policy upholds the university's collective commitments to fairness, equity, and integrity.

(Adapted from [Carleton University's Academic Integrity Policy](#), 2021).

### Examples of actions that do not adhere to Carleton's Academic Integrity Policy include:

- Plagiarism
- Accessing unauthorized sites for assignments or tests
- Unauthorized collaboration on assignment and exams
- Using artificial intelligence tools such as ChatGPT when your assessment instructions say that it is not permitted

Please review the checklist [linked here](#) to ensure you understand your responsibilities as a student with respect to academic integrity and this course.

## Sanctions for Not Abiding by Carleton's Academic Integrity Policy

A student who has not upheld their responsibilities under Carleton's Academic Integrity Policy may be subject to one of several sanctions. A list of standard sanctions in science can be found [here](#).

Additional details about this process can be found on the [Faculty of Science Academic Integrity website](#). Students are expected to familiarize themselves with and follow the [Carleton University Student Academic Integrity Policy](#). The Policy is strictly enforced and is binding on all students.

## Student Rights & Responsibilities

Students are expected to act responsibly and engage respectfully with other students and members of the Carleton and the broader community. See the [7 Rights and Responsibilities Policy](#) for details regarding the expectations of non-academic behaviour of students. Those who participate with another student in the commission of an infraction of this Policy will also be held liable for their actions.

## Student Concerns

If a concern arises regarding this course, **your first point of contact is me**: Email or drop in during student hours and I will do my best to address your concern. If I am unable to address your concern, the next points of contact are (in this order):



**Note:** You can also bring your concerns to [Ombuds services](#).