

# Physical Applications of Fourier Analysis

PHYS 4203/5313

**Course Instructor:** Tong Xu

**How to address me:** Tong

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

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

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.

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

Student Hours: TBD.

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

**Class Location:** Online via BrightSpace (BBB)

**Class Times:** Tuesday & Thursday, 11:35am-12:55pm

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

## 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. at a senior undergraduate level, 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 introductory 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 including Abel, Nyquist, Heaviside, Shannon, Hounsfield, and Cormack.

## 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

### Technology Checklist:

- An internet-enabled computer (laptop/desktop)
- Access to reliable internet
- Webcam
- Headset with microphone

### Assessments

There are **six assignments**, with one assignment due about every second week. Late assignments will not be accepted. **Top 5 assignments** will be used for your assignment mark in the course. Clarity, rigour, and organization are important parts of your solutions.

### Project (PHYS 5313 students only)

Each student in Phys 5313 will write a report (max 15 pages) and make a class presentation (~20 min + questions) on an application of Fourier analysis of his/her 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. This term the presentations will be over the web. 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 take place remotely with e-proctoring.

The midterm exam (75 min) will take place on **Oct 21<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 PHYS 4203	GRADE VALUE PHYS 5313
ASSIGNMENTS	45%	40%
MIDTERM	20%	20%
FINAL EXAM	35%	30%

## 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.

## Special Information Regarding COVID-19

All members of the Carleton community are required to follow COVID-19 prevention measures and all mandatory public health requirements (e.g., wearing a mask, physical distancing, hand hygiene, respiratory and cough etiquette) and mandatory self-screening prior to coming to campus daily.

If you feel ill or exhibit COVID-19 symptoms while on campus or in class, please leave campus immediately, self-isolate, and complete the mandatory symptom reporting tool. For purposes of contact tracing, attendance will be taken in all classes and labs. Participants can check in using posted QR codes through the cuScreen platform where provided. Students who do not have a smartphone will be required to complete a paper process as indicated on the COVID-19 website.

All members of the Carleton community are required to follow guidelines regarding safe movement and seating on campus (e.g., directional arrows, designated entrances and exits, designated seats that maintain physical distancing). In order to avoid congestion, allow all previous occupants to fully vacate a classroom before entering. No food or drinks are permitted in any classrooms or labs.

For the most recent information about Carleton's COVID-19 response and required measures, please see the University's COVID-19 webpage and review the Frequently Asked Questions (FAQs). Should you have additional questions after reviewing, please contact [covidinfo@carleton.ca](mailto:covidinfo@carleton.ca).

Please note that failure to comply with University policies and mandatory public health requirements, and endangering the safety of others are considered misconduct under the Student Rights and Responsibilities Policy. Failure to comply with Carleton's COVID-19

procedures may lead to supplementary action involving Campus Safety and/or Student Affairs.

## Note About COVID-19 & Mental Health

The global pandemic has led to extra stress and uncertainty for everyone, and while we may all be experiencing the same storm, this does not mean that we are all in the same boat! 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](#).

## Children & video sessions

You are welcome to have children with you during video sessions as I fully understand that childcare situations may be complicated for many of us at this time. Do your best to participate and engage, but also please get in touch with me if you have any questions or concerns.

## 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

ABS = Student absent from final exam

DEF = Deferred

FND = (Failed, no Deferred) = student could not pass even with 100% on final exam

## Academic Accommodations, Regulations, Plagiarism, Etc.

Carleton University is committed to providing access to the educational experience in order to promote academic accessibility for all individuals.

Academic accommodation refers to educational practices, systems and support mechanisms designed to accommodate diversity and difference. The purpose of

accommodation is to enable students to perform the essential requirements of their academic programs. At no time does academic accommodation undermine or compromise the learning objectives that are established by the academic authorities of the University. More information can be found at: <https://students.carleton.ca/course-outline/>

University rules regarding registration, withdrawal, appealing marks, and most anything else you might need to know can be found on the university's website, here:

<https://calendar.carleton.ca/undergrad/regulations/academicregulationsoftheuniversity/>

## **Academic Accommodations for Students with Disabilities**

If you have a documented disability requiring academic accommodations in this course, please contact the Paul Menton Centre for Students with Disabilities (PMC) at 613-520-6608 or [pmc@carleton.ca](mailto:pmc@carleton.ca) for a formal evaluation or contact your PMC coordinator to send your instructor your Letter of Accommodation at the beginning of the term. You must also contact the PMC no later than two weeks before the first in-class scheduled test or exam requiring accommodation (if applicable). After requesting accommodation from PMC, meet with your instructor as soon as possible to ensure accommodation arrangements are made. For more details, visit the [Paul Menton Centre website](#).

## **Addressing Human Rights Concerns**

The University and all members of the University community share responsibility for ensuring that the University's educational, work and living environments are free from discrimination and harassment. Should you have concerns about harassment or discrimination relating to your age, ancestry, citizenship, colour, creed (religion), disability, ethnic origin, family status, gender expression, gender identity, marital status, place of origin, race, sex (including pregnancy), or sexual orientation, please contact the [Department of Equity and Inclusive Communities](#) at [equity@carleton.ca](mailto:equity@carleton.ca).

## **Religious Obligations**

Please contact me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, please review the [Student Guide to Academic Accommodation \(PDF, 2.1 MB\)](#).

## **Survivors of Sexual Violence**

As a community, Carleton University is committed to maintaining a positive learning, working and living environment where sexual violence will not be tolerated, and where survivors are supported through academic accommodations as per Carleton's Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit: <https://carleton.ca/sexual-violence-support/>

## **Accommodations for Missed Work**

Carleton recognizes that these are unprecedented times during the COVID-19 pandemic, and that students may be experiencing greater stress and other life factors that are not in their control. As a result, Carleton has put into place a protocol for students to apply for accommodations using a self-declaration form in the event of missed work. The form can be found at: <https://carleton.ca/registrar/wp-content/uploads/self-declaration.pdf>

## **For Pregnancy**

Please contact me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, please review the [Student Guide to Academic Accommodation \(PDF, 2.1 MB\)](#).

## **Accommodation for Student Activities**

Carleton University recognizes the substantial benefits, both to the individual student and for the university, that result from a student participating in activities beyond the classroom experience. Reasonable accommodation must be provided to students who compete or perform at the national or international level. Please contact me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, see the [Senate Policy on Accommodation for Student Activities \(PDF, 25KB\)](#).

## **Academic Integrity**

Academic misconduct undermines the values of honesty, trust, respect, fairness, and responsibility that we expect in this class. 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

## Sanctions for not abiding by Carleton's Academic Integrity Policy

A student who has not adhered to Carleton's Academic Integrity Policy may be subject to one of several sanctions:

1. If you take full responsibility for your actions, and it is the first time you have violated the policy, you will receive zero on the assessment. If you are found to have violated the policy but do not take responsibility, an additional grade deduction will be applied (e.g. an A- will become a B+)
2. Subsequent violations of the policy may result in more severe sanctions such as failing the course, suspension from all studies and/or expulsion.

## Process of an Academic Misconduct Investigation

**Step 1:** The instructor believes misconduct has occurred and submits documentation to the Dean of the Faculty of Science.

**Step 2:** The Dean reviews documentation and can proceed with or dismiss the allegation.

**Step 3:** If sufficient evidence, the student receives an allegation statement by email. Ombuds services is copied on the email.

**Step 4:** The student provides a written response to the evidence provided.

**Step 5:** Either party may request a meeting between student, dean, and the ombudsperson.

**Step 6:** Dean informs the student of the decision.

**Appeal:** Student has the right to appeal the decision.

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.

## Plagiarism

Plagiarism is the passing off of someone else's work as your own and is a serious academic offence. For the details of what constitutes plagiarism, refer the Faculty of Science Academic Integrity website. To further understand Academic Integrity, consider attending the Learning and Support Academic Integrity Workshop.

## What are the Penalties for Plagiarism?

A student found to have plagiarized an assignment may be subject to one of several penalties including: expulsion; suspension from all studies at Carleton; suspension from full-time studies; and/or a reprimand; a refusal of permission to continue or to register in a specific degree program; academic probation; award of an FNS, Fail, or an ABS.

## What are the Procedures?

3. All allegations of plagiarism are reported to the Dean of Faculty of Science. Documentation is prepared by instructors and/or departmental chairs.
4. The Dean writes to the student and the University Ombudsperson about the alleged plagiarism.
5. The Dean reviews the allegation. If it is not resolved at this level then it is referred to a tribunal appointed by the Senate.

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.

## Assistance for Students

Academic and Career Development Services: <http://carleton.ca/sacds/>

Writing Services: <http://www.carleton.ca/csas/writing-services/>

Peer Assisted Study Sessions (PASS): <https://carleton.ca/csas/group-support/pass/>

Math Tutorial Centre: <https://carleton.ca/math/math-tutorial-centre/>

Science Student Success Centre: <https://sssc.carleton.ca/>

Chapter	Monday	Tuesday	Wednesday	Thursday	Friday
<b>January</b>					
Intro	4	5	6	7	8
Ch. 1	<i>Intro Quiz due 11:59pm</i> 11	12	13	14	15
Ch. 2	18	<i>Quiz 1 due 11:59pm</i> 19	20	21	22
Ch. 5	25	26	27	28	29
<b>February</b>					
Ch. 6 & 9	1	2	3	4	5
Review	8	9	10	11	Midterm #1 11:00am-2:00pm 12
No Classes	<i>Winter Break</i> 15	<i>Winter Break</i> 16	<i>Winter Break</i> 17	<i>Winter Break</i> 18	<i>Winter Break</i> 19
Ch. 12	22	23	24	25	26
<b>March</b>					
Ch. 15	1	2	3	4	5
Ch. 16	8	<i>Quiz 2 due 11:59pm</i> 9	10	11	12
Ch. 24	15	16	17	18	Midterm #2 11:00am-2:00pm 19
Ch. 25	22	23	24	25	26
Ch. 28	29	<i>Quiz 3 due 11:59pm</i> 30	31	1	2
<b>April</b>					
Ch. 27	5	6	7	8	<i>Optional Assignment due 11:59pm</i> 9
Review	12	13	<i>Last Day of Classes</i> 14	15	16