



**520.432/520.632 MEDICAL IMAGING SYSTEMS**  
**Syllabus**  
**FALL 2021**

**Description**

An introduction to the physics, instrumentation, and signal processing methods used in general radiography, X-ray computed tomography, ultrasound imaging, magnetic resonance imaging, and nuclear medicine. The primary focus is on the methods required to reconstruct images within each modality, with emphasis on the resolution, contrast, and signal-to-noise ratio of the resulting images. Students will additionally engage in hands-on activities to reconstruct medical images from raw data.

**Prerequisites**

EN.580.222 or EN.520.214 Signals and Systems

**Instructor**

Muyinatu Bell <mledijubell@jhu.edu>  
Assistant Professor  
Office Hours: Tuesdays 11:45am-12:45pm  
(see Blackboard for Zoom link)

**Teaching Assistants**

Eduardo Gonzalez <egonza31@jhmi.edu>	Office Hours:
Junyu Chen <jchen245@jhu.edu>	Mondays 9-11am ET
Alycen Wiacek <awiacek1@jhu.edu>	Barton Hall 223C

**Lecture Times**

TTh 10:30-11:45am  
Hackerman 320 (Section 01)  
Online (section 90, see Blackboard for Zoom link)

**Textbook**

Medical Imaging Signals and Systems (2nd Edition) by Prince and Links, 2015.  
Errata for textbook (as of December 12, 2016): [https://pulselab.jhu.edu/wp-content/uploads/2017/08/MISS\\_TextbookErrata\\_122116.pdf](https://pulselab.jhu.edu/wp-content/uploads/2017/08/MISS_TextbookErrata_122116.pdf)

**Online Resources**

Please log in to Blackboard for all materials related to this course.

**Course Objectives**

- (1) Students will learn the physics of image formation in medical imaging
- (2) Students will learn the main instrumentation used in medical imaging
- (3) Students will learn the mathematics of image reconstruction
- (4) Students will learn how to assess image quality in medical imaging

- (5) Students will learn how to model and analyze medical imaging systems using signals and systems concepts and mathematics
- (6) Students will learn how to manipulate real medical imaging data

### **Course Topics**

- Signal and image processing concepts
- Image quality
- Physics of radiography
- Projection radiography
- Computed tomography
- Physics of nuclear medicine
- Nuclear medicine
- Ultrasound imaging
- Ultrasound physics
- Nuclear magnetic resonance
- Magnetic resonance imaging

### **Course Expectations & Grading**

#### **Lectures**

Lectures will be delivered synchronously and edited recordings approved by the instructor will be available afterward whenever possible. **Students do not have the instructor's permission to record lectures.** Attendance during the synchronous lectures is strongly encouraged.

#### **Study Groups**

Students benefit from interaction with each other and are requested to form and report study teams to the instructor and TAs. If assistance forming the study team is needed, please report this need by the end of the first week of class to receive an automated study team assignment.

#### **Homework**

Homework problems will be assigned with each new topic, and they are due at the beginning of class on each indicated due date (see the course schedule for homework due dates). Submissions will be facilitated through Blackboard. No late submissions will be accepted.

#### **Examinations**

There will be three synchronous online examinations (see the course schedule for their dates). These exams address the most recent material; thus, they are not cumulative. The final exam will take place in the registrar-scheduled 3-hour exam period during exam week.

Exams will be posted on Blackboard at the start of class, will be timed, and must be submitted before the time expires to receive credit. No late exam submissions will be accepted. These exams will occur synchronously and may be partially administered through **Respondus LockDown Browser and Monitoring Tools**. All students are required to download the Respondus LockDown Browser and become familiar with the tool at least 24 hours before the start of any online exams (<https://www.respondus.com/lockdown/download.php?id=123533816>; this is the

download link is for JHU Blackboard users). While familiarizing yourself with the platform, take note of the following details and requirements:

- You will need to use Respondus Lockdown Browser after logging into Zoom and showing your video first.
- When it comes time to take the exam, enter the Blackboard course site to start the exam. The LockDown browser will start automatically.
- Respondus Monitoring records your activities during the exam with a webcam. You do not have to install additional software beyond the Respondus LockDown Browser, but you will need to connect a webcam to the device on which you are taking the exam. The Monitoring tool will record you while you take the exam, and the recording will be available for viewing by the instructor afterward.
- Download and install the Respondus LockDown Browser well before your exam so you can ensure it is installed properly. It is not recommended to use a Google Chromebook device with LockDown browser.
- Choose a location where you won't be interrupted to take the exam.
- You will be unable to exit the exam until all questions are completed and submitted.
- General JHU help page: <https://uis.jhu.edu/respondus/>

### **Presentations**

All students taking the graduate version of this course are required to give a presentation to the entire class that delves deeper into one of the topics discussed in class. This topic must be related to medical imaging, and proposals for the selected topic must be approved by Professor Bell (see course schedule for proposal due dates). There will be a question-and-answer period after each presentation and student performance during both the presentation and the question-and-answer period will be evaluated. Undergraduate student participation is particularly encouraged during the question period and this participation will count toward your final grade.

### **Grading**

The final numerical score for the course will be based on the following breakdown:

Homework 35% (21% Submission + 14% Detailed Grading)

Exams 35%

Presentations\* 10%

Final 20%

\*Includes overall presentation, questions asked, and grad student responses to questions

## Key Dates

Date	Subject	Reading Assignment	HW # & Due Date
8/31	Introduction to Medical Imaging, Review of Signals & Systems	Chapters 1,2	
9/2	Review of Fourier Transforms	Chapter 2	#1 - 9/7
9/7	Image Quality: Contrast, Resolution	Chapter 3	
9/9	Image Quality: Noise, SNR, Accuracy	Chapter 3	#2 - 9/14
9/14	Physics of Radiography	Chapter 4	
9/16	Projection Radiography	Chapter 5	#3 - 9/21
9/21	Projection Radiography: Image Formation	Chapter 5	
<b>9/23</b>	<b>Exam 1</b>		
9/28	Computed Tomography (CT): Equipment, Image Formation	Chapter 6	
9/30	CT: Image Formation (cont.), Image Quality	Chapter 6	#4 - 10/5
10/5	Physics of Nuclear Medicine (NM)	Chapter 7	
10/7	NM Planar Scintigraphy	Chapter 8	#5 - 10/12
10/12	NM Planar Scintigraphy: Image Formation, Image Quality	Chapter 8	
10/14	SPECT & PET: Image Formation	Chapter 9	
<b>10/19</b>	<b>Exam 2</b>		
10/21	Ultrasound (US) Imaging Systems	Chapter 11a	
10/26	US Physics	Chapter 10	
10/28	US Steering, Focusing, Beamforming, Image Quality	Chapter 11b	#6 - 11/2
11/2	Magnetic Resonance Imaging (MRI): Instrumentation, Data Acquisition, Physics	Chapters 13a, 12a	
11/4	MRI Contrast, Frequency Encoding, Phase Encoding	Chapter 12b, 13a	#7 - 11/9
11/9	MRI Pulse Sequences, Image Reconstruction, Image Quality	Chapter 13b	
<b>11/11</b>	<b>Exam 3</b>		
11/16	Hands-on Image Formation (Part 1)		
11/18	Hands-on Image Formation (Part 2) <b>Grad Student Proposals Due</b>		#8 - 11/30
11/23	Thanksgiving Break		
11/25	Thanksgiving Break		
11/30	Grad Student Presentations		
12/2	Grad Student Presentations		
12/13-12/21	Final Exam (6-9pm)		

## Assignments & Readings

Expected reading assignments are indicated in the syllabus (see above) and associated homework problems will be assigned on Blackboard as we progress through the material.

## Ethics

The strength of the university depends on academic and personal integrity. In this course, you must be honest and truthful. Ethical violations include cheating on exams, plagiarism, reuse of assignments, improper use of the Internet and electronic devices, unauthorized collaboration, alteration of graded assignments, forgery and falsification, lying, facilitating academic dishonesty, and unfair competition. Report any violations you witness to the instructor.

In addition, the specific ethics guidelines for this course are as follows:

**Homework:** You are free to work together to solve the assigned homework problems, however, the work appearing on your submitted homework assignment must be your own.

**Examinations:** Your examination solutions must be your own. The examinations are closed book and closed notes. However, for the 1st in-class exam, you may bring one 8-1/2" by 11" sheet of paper with any equations or notes *handwritten* on both sides. For the 2nd in-class exam, you may bring two such equation/note sheets. For the 3<sup>rd</sup> exam and final exam, you may bring three such equation/note sheets. PDA's, computers, tablets, cell phones, pagers, and other electronic aids or storage devices (except for standard calculators) are not allowed to be used during exams. Equation sheets that are used for Exams 1-3 and the final exam must be handwritten—no photocopied and/or miniaturized text will be permitted.

**More information:** After your formal educational studies, you will be expected to continue to maintain integrity in all that you do in graduate school or in your profession. Many societies and professional organizations have their own ethical codes. One worth reading is the IEEE Code of ethics: <http://www.ieee.org/about/corporate/governance/p7-8.html>. More information about JHU misconduct policies is available on the university's website:

- For undergraduates: <http://e-catalog.jhu.edu/undergrad-students/student-life-policies/>
- For graduate students: <http://e-catalog.jhu.edu/grad-students/graduate-specific-policies/>

You may also consult the associate dean of student conduct (or designee) by calling the Office of the Dean of Students at 410-516-8208 or via email at [studentconduct@jhu.edu](mailto:studentconduct@jhu.edu).

## Personal Wellbeing

- Because of the ongoing COVID-19 pandemic special requirements will be in effect this term, and these may vary during the term. Please keep updated with these at the following sites:
  - University information: <https://covidinfo.jhu.edu/>
  - Whiting School of Engineering information: <https://engineering.jhu.edu/covid-19/>
- As of the start of the term all students, instructors and staff must complete health screening daily using the Prodensity app before coming to campus. **Masks must be worn properly at all times while in the classroom and other indoor spaces.** Vaccination is required unless an exception has been granted by the university for health or religious reasons. Periodic

asymptomatic testing may be required. Please follow the university guidance faithfully.

- The Johns Hopkins COVID-19 Call Center (JHCCC), which can be reached at 443-287-8500 seven days a week from 7 a.m. to 7 p.m., supports all JHU students, faculty, and staff experiencing COVID-19 symptoms. Primarily intended for those currently within driving distance of Baltimore, the JHCCC will evaluate your symptoms, order testing if needed, and conduct contact investigation for those affiliates who test positive. More information on the JHCCC and testing is on the [coronavirus information website](#).
- If you are sick please notify the instructor by email so that we can make appropriate accommodations should this affect your ability to attend class, complete assignments, or participate in assessments. The [Student Health and Wellness Center](#) is open and operational for primary care needs. If you would like to speak with a medical provider, please call 410-516-8270, and staff will determine an appropriate course of action. See also <https://studentaffairs.jhu.edu/student-life/student-outreach-support/absences-from-class/illness-note-policy/>
- All students with disabilities who require accommodations for this course should contact the instructor at their earliest convenience to discuss their specific needs. If you have a documented disability, you must be registered with the JHU Office for Student Disability Services (101 Shaffer Hall; 410-516-4720; <http://web.jhu.edu/disabilities/>) to receive accommodations.
- Students who are struggling with anxiety, stress, depression or other mental health related concerns, please consider connecting with resources through the JHU Counseling Center. The Counseling Center will be providing services remotely to protect the health of students, staff, and communities. Please reach out to get connected and learn about service options based on where you are living this fall at 410-516-8278 and online at <http://studentaffairs.jhu.edu/counselingcenter/>.
- Student Outreach & Support helps students manage physical and mental health concerns, personal and family emergencies, financial issues, and other obstacles that may arise during their college experience. Students can self-refer or refer a friend who may need extra support or help getting connected to resources. To connect with SOS, please visit this website: <https://studentaffairs.jhu.edu/student-life/student-outreach-support/> or email [deanofstudents@jhu.edu](mailto:deanofstudents@jhu.edu), call 410-516-7857, or students can schedule to meet with a Case Manager by visiting the Student Outreach & Support website and filling out a referral form online.

### **Classroom Climate**

As your instructor, I am committed to creating a classroom environment that values the diversity of experiences and perspectives that all students bring. Everyone here has the right to be treated with dignity and respect. Fostering an inclusive climate is important because research and my experience show that students who interact with peers who are different from themselves learn new things and experience tangible educational outcomes. Please join me in creating a welcoming and vibrant classroom climate. Note that you should expect to be challenged intellectually by me, the TAs, and your peers, and at times this may feel uncomfortable. Indeed, it can be helpful to be pushed sometimes in order to learn

and grow. But at no time in this learning process should someone be singled out or treated unequally on the basis of any seen or unseen part of their identity.

If you ever have concerns in this course about harassment, discrimination, or any unequal treatment, or if you seek accommodations or resources, please share them directly with the instructor or the TAs. Your communication will be taken seriously and mutually acceptable resolutions and accommodations will be sought. Reporting will never impact your course grade. You may also share concerns with the department head, the Assistant Dean for Diversity and Inclusion (Darlene Saporu, [dsaporu@jhu.edu](mailto:dsaporu@jhu.edu)), or the Office of Institutional Equity ([oi@jhu.edu](mailto:oi@jhu.edu)). In handling reports, your privacy will be protected as much as possible, but faculty and staff are required to officially report information for some cases (e.g. sexual harassment).

### **Family Accommodations Policy**

You are welcome to bring a family member to class on occasional days when your responsibilities require it (for example, if emergency child care is unavailable, or for health needs of a relative). Please be sensitive to the classroom environment, and if your family member becomes uncomfortably disruptive, you may leave the classroom and return as needed.

### **University Policy on Incompletes**

The university recognizes that the Fall 2021 semester is surrounded with uncertainty and many students may find themselves in unexpected situations where study is difficult if not impossible. Students who are confronted with extraordinary circumstances that interfere with their ability perform their academic work may request an incomplete grade from the instructor. Approval of such a request is not automatic, and every effort will be made to accommodate students dealing with illness in the family and other pandemic-related hardships. The instructor will establish a timetable for submitting the unfinished work with a final deadline no later than the end of the third week of the Spring 2022 semester. Exceptions to this deadline require a petition from the instructor to the student's academic advising office before the deadline expires. When entering an Incomplete grade in SIS, a reversion grade will also be included, representing the grade the student will receive if s/he does not complete the missing work by the deadline.

### **Deadlines for Adding, Dropping and Withdrawing from Courses**

Students may add a course up to **September 10, 2021**. They may drop courses up to **October 10, 2021** provided they remain registered for a minimum of 12 credits. Between **October 11 and November 12, 2021**, a student may withdraw from a course with a W on their academic record. A record of the course will remain on the academic record with a W appearing in the grade column to indicate that the student registered and then withdrew from the course.

For more information on these and other academic policies, see <https://e-catalogue.jhu.edu/engineering/full-time-residential-programs/undergraduate-policies/academic-policies/grading-policies/>

**ABET Outcomes**

- Ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics (1)
- Ability to communicate effectively with a range of audiences (3)
- Ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives (5)
- Ability to acquire and apply new knowledge as needed, using appropriate learning strategies data, and use engineering judgment to draw conclusions (7)