# BMEN 509 / BMEN 623
## Introduction to Biomedical Imaging
# Deliverable 1
Radiation Physics, Image Processing & Quality

**Due Date:** Monday, February 9, 2026 at 11:59 PM
**Weight:** 6% of final grade
**Submission:** D2L Dropbox (.ipynb + .pdf)

## 1 Overview

In this deliverable, you will apply the concepts from Weeks 2–5 (Chapters 1, 2, and 4) through a combination of conceptual questions and guided coding exercises. You will explore radiation physics, X-ray production, photon interactions, spatial resolution, noise sources, and image quality optimization. This deliverable is designed to strengthen your physical intuition and practical problem-solving skills.

**Learning Objectives Assessed**

- **CLO1:** Demonstrate knowledge of fundamental physics underlying biomedical imaging
- **CLO2:** Predict and evaluate image quality based on standardized criteria
- **CLO3:** Choose and apply appropriate algorithms for image processing and analysis
- **CLO5:** Explain the physics and algorithms used in image formation

## 2 Materials

Download the starter notebook from the course GitHub repository:

**Repository:** github.com/EthanMacDonald/BMEN509-623_Deliverable_1
Click "Code" → "Download ZIP" or clone using Git

The repository contains:

- `README.md` – Assignment overview and quick-start instructions
- `deliverable-01-instructions.pdf` – This document
- `deliverable-01-starter.ipynb` – Jupyter Notebook with questions and coding exercises
- `figures/` – Images referenced in the notebook

## 3 Deliverable Structure

This deliverable consists of six parts with conceptual questions and coding exercises. **Estimated time: 6 hours.**

### 3.1 Part 1: Radiation Physics

- Ionizing radiation classification and energy scales
- X-ray production mechanisms (bremsstrahlung and characteristic X-rays)
- Questions Q1, Q2

### 3.2 Part 2: Photon Interactions

- Photoelectric effect and Compton scattering
- Beer-Lambert law and attenuation
- Half-value layer calculations
- Questions Q3, Q4

### 3.3 Part 3: Spatial Resolution

- Point spread function and system blurring
- Modulation transfer function (MTF)
- Questions Q5, Q6

### 3.4 Part 4: Noise and Image Quality

- Noise sources and signal-to-noise ratio (SNR)
- Coding Exercise 1: SNR analysis
- Question Q7

### 3.5 Part 5: Quantum Noise and Dose Analysis

- Quantum noise and dose optimization
- Coding Exercises 2, 3, 4: Dose-quality trade-offs

### 3.6 Part 6: Comprehensive Design Challenge

- Lung cancer screening protocol design
- Question Q8: Integration of all concepts

## 4 Submission Requirements

**You must submit TWO files to D2L:**

1. **Jupyter Notebook** (`.ipynb`): Your completed notebook with all code, outputs, and written analysis. All cells must be executed in order.
2. **PDF Export** (`.pdf`): Export your notebook to PDF (File → Export as PDF, or print to PDF). Verify all figures and equations render correctly.

**File naming convention:** `LastName_FirstName_Deliverable1.ipynb` and `.pdf`

## 5 Grading

This deliverable is graded using a **qualitative rubric** that rewards thoughtful design, creativity, and sound reasoning—not just correct answers. Each component is evaluated on a 7-level scale:

| Level | Description | Approximate % |
|---|---|---|
| Outstanding | Exceptional work; exceeds expectations significantly | 95–100% |
| Excellent | High quality; demonstrates mastery | 85–94% |
| Good | Solid work; meets expectations well | 75–84% |
| Satisfactory | Adequate; meets basic expectations | 65–74% |
| Poor | Below expectations; significant gaps | 50–64% |
| Very Poor | Major deficiencies; minimal understanding shown | 25–49% |
| Incomplete | Missing or not attempted | 0–24% |

Complex questions have **multiple rubric components** (e.g., algorithm design, physical reasoning, interpretation). See the detailed rubric on D2L.

## 6 Academic Integrity

- You may discuss general concepts with classmates, but all code and written analysis must be your own work.
- You may use course materials, textbooks, and documentation (NumPy, SciPy, etc.).
- You may use AI tools (e.g., GitHub Copilot, ChatGPT) as a *learning aid*, but you must understand and be able to explain every line of code you submit. Blindly copying AI-generated code without understanding is a violation of academic integrity.
- Cite any external resources beyond course materials.

## 7 Late Policy

Per the course syllabus, late submissions are penalized as follows:

| Days Late | Penalty |
|---|---|
| 0–24 hours | 25% deduction |
| 24–48 hours | 50% deduction |
| 48–72 hours | 75% deduction |
| More than 72 hours | Not accepted (0%) |

Extensions may be granted for documented extenuating circumstances if requested before the deadline.

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*This deliverable is designed to challenge you. Start early, think creatively, and enjoy the process!*