Course Outline: Physics 5206 – 2022W
Radiotherapy Physics

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Contents

1 Contact information

1.A Instructor

Instructor: Dave Rogers (he/him/his)
Office: Room 2450 Herzberg Building (Inco (S-W) Wing, far corner)
"Office" hours: One-on-one meetings can be immediately after lectures or arranged individually by e-mail. Will be by zoom until restrictions lessened. If you specify what you want to talk about ahead of time, I can try to have appropriate notes etc available (but not essential).
Office Phone 520-2600 ext 4374 (but email essential until offices used!)
email: drogers(remove_this)@physics.carleton.ca
personal web page: http://www.physics.carleton.ca/~drogers

1.B Course location and times

Lectures are from 10 to 11:30, Tuesdays and Thursdays. I will try to start at 10 and finish at 11:30 latest, or earlier if we reach a natural stopping point.

When in-person lectures are allowed again, lectures will be held in the SunRay lab which is room 3349 in the Herzberg Building. It is a relatively large room so I will ask you to sit well spaced out.

In the meantime, we will be meeting for lectures via zoom using https://carleton-ca.zoom.us/j/9286866976. It is best, if not essential, to install zoom software on your computer (which I assume everyone has done now that we are 2 years into this pandemic!) I request that you use a first and last name to identify yourself on zoom and please have the video on in order to hopefully foster some interaction. I have not used zoom much as the host, so I apologize if it takes me some time to master this methodology.

1.C Course Web page

The course web page is at http://www.physics.carleton.ca/~drogers/phy5206/
This site is password protected. The 2022 password and username will be given at the first lecture. Please do not give the username and password to anyone outside the course. I monitor site usage.
The current username is `W20DWOR` and the password is `irs` but I will give out new values at the first lecture.

The web page includes a course calendar with various tentative dates. Assignments etc will be added as we go.

2 Course introduction/overview

2.A Course delivery

The book I am working on is designed for this course. The first few chapters should be almost entirely review but it is essential to master the material.

Rather than giving lectures which just give highlights of what is in the book, I will ask you to read various parts before a lecture and then during lectures there will be time to ask questions about what you have read, and if there are few questions, I will ask various questions and ask you to give your answers via the chat feature, with responses being to me only (not everyone). These responses will not be for marked, but will help me judge how much you have understood of what you were asked to read. I will also go through some of my standard slide sets and focus on a few of the more interesting features.

Lectures will not be recorded.

2.B Course objectives

The course objectives can be deduced by the course outline in section 10 below, and the more detailed Learning Objectives in section 11(also below). The overall objectives are:

- to provide an overview of modern radiotherapy, its purposes, its techniques and the importance of physics in its practice.
- to provide a fundamental understanding of the physics of radiotherapy, from the nature of radiotherapy treatment fields to the methods to calculate and measure clinical radiation dose distributions with special (but not exclusive) emphasis on ion chamber dosimetry and clinical dosimetry protocols.
- to provide a solid basis for understanding clinical treatment planning with emphasis on fundamentals rather than clinical software.
- to introduce Monte Carlo techniques as used in radiotherapy and use calculated results to understand the physics of radiotherapy treatment fields and clinical instrumentation.
- to provide an introduction to a wide range of modern techniques such as IMRT, IGRT, tomotherapy, CyberKnife, proton therapy, brachytherapy.

2.C Books

The book I am writing is very much a work in progress. As I write this (Jan 2, 2022) 16 of 26 chapters are drafted and I have partial notes for a couple more (about 480 pages in all). I will endeavour to make pdf versions of chapters and/or copies of lecture notes available before each lecture. This may be literally only an hour or two before the lecture so please check your email and/or the web page before each lecture.

There is a list of books about radiotherapy physics is in the book's Appendix A.

As a backup for those parts of the course for which I don't yet have chapters ready (mostly on specific detector types), an excellent reference is individual chapters in:
Clinical Dosimetry Measurements in Radiotherapy, eds D. W. O. Rogers and J. E. Cygler, Medical Physics Publishing, Madison Wi, 2009 (AAPM Summer School) [RM849 .A44 2009A disc, on reserve RM849 .A44 2009].

3 Tentative Marking Scheme

The following is subject to change and/or comment during the first part of the course.

Problem assignments	30%	
project/presentation	10%	
Mid-terms(2)	30%	If only 1 mid-term, it will be 20% and the final 40%
Final	30%	

There will be between 4 and 7 assignments. I will mark for the neatness and clarity of the solutions as well as for the correctness of the answer. I will not struggle to read your writing, I will just mark it wrong (it takes me longer to mark a set than for you to do one, so please be considerate). On some assignments I will only mark some of the questions since the value of problems is in doing them, not in getting marks for them. You will not know in advance which problems will be marked. We will take up all assignments in class so you can check your own work.

The purpose of assignments is to help you learn the material. I don't mind if you discuss issues raised amongst yourselves, but please do not copy each others answers. It is very easy to tell when such copying is happening as a marker, and I don't want to see it.

Term tests are tentatively on Thurs Feb 17 (L12, right before reading week) and Thurs March 31 (L22) and take place during the regularly schedule lecture time. Dates possibly adjusted to avoid conflict with Phy5208 tests.

When assigning final marks, I may adjust the overall marking scheme to give a better representation of how you have done in the class. These adjustments will be done so that: (a) they do not change the ranking of students within 2%; (b) they only increase any student's mark; and (c) the same algorithm is applied to everyone if consistent with (a) and (b). A common example is ignoring mid-term I's mark.

4 Project/Presentation

After the last lecture (which is on Tues April 12), one morning (tentatively Thurs April 14) will be devoted to student presentations on projects which will be assigned by the end of January. Each student will have about 20 minutes to speak and will be required to prepare a 1 to 3 page handout on their topic. A list of possible topics will be provided around the end of January and you will be asked to chose your topic, possibly after negotiating with another student (to avoid duplication). By class on Thursday March 10, each of you must prepare a 3 sentence/point summary of the papers you intend to review (suggestions can be made but the final choice (subject to review in early March) will be yours). Then 3 weeks prior to the talks (by Thurs March 24) you must each give me a draft of your handout which will be revised after my review and then handed out to all students by the last class on April 12. You will only be marked on your presentation and the final draft of your handout, so even if I have major comments on your draft handout, you have a chance to recover (like a referee's comments on a research paper) - but it pays to get the draft to me in good time so you have time to rework it if needed.

5 Academic Accommodation

You may need special arrangements to meet your academic obligations during the term because of disability, pregnancy or religious obligations. Please review the course outline promptly and write to me during the first two weeks of class with any requests for academic accommodation, or as soon as possible after the need for accommodation is known to exist.

It takes time to review and consider each request individually, and to arrange for accommodations where appropriate. Please make sure you respect these timelines particularly for in-class tests, mid-terms and final exams, as well as any change in due dates for papers.

You can visit the Equity Services website to view the policies and to obtain more detailed information on academic accommodation at http://carleton.ca/equity/accommodation

6 Student Academic Integrity Policy

Much of the following is quoted directly from Carleton documents.

Plagiarism and cheating at the graduate level are viewed as being particularly serious and the sanctions imposed are accordingly severe. Students are expected to familiarize themselves with and follow the Carleton University Student Academic Integrity Policy (see http://carleton.ca/registrar/academic-integrity/. and/or https://carleton.ca/tls/teachingresources/administrative-pedagogy/academic-integrity-resources/).

The Policy is strictly enforced and is binding on all students. Plagiarism and cheating - presenting another's ideas, arguments, words or images as your own, using unauthorized material, misrepresentation, fabricating or misrepresenting research data, unauthorized cooperation or collaboration or completing work for another student - weaken the quality of the graduate degree. Academic dishonesty in any form will not be tolerated. Students who infringe the Policy 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; or a grade of Failure in the course.

To be specific on one point. When doing your project handouts, directly quoting things found on the web without attribution and quotation marks is plagiarism. Similarly, using figures from the web without clear citation of the source is plagiarism.

7 Copyright materials

The following is a quote of wording suggested by Carleton:
"I would like to remind you that my lectures and course materials, including power point presentations, outlines, and similar materials, are protected by copyright. I am the exclusive owner of copyright and intellectual property in the course materials. You may take notes and make copies of course materials for your own educational use. You may not and may not allow others to reproduce or distribute lecture notes and course materials publicly for commercial purposes without my express written consent."

I will be making available drafts of chapters from a book I am trying to write for this

course. **These drafts must NOT be distributed outside the course** as they are preliminary and I have not sought permissions yet for many of the figures taken from elsewhere. I will give final copies to all students giving feedback on these drafts.

8 Aside on SI Units

To the extent possible, I want the entire course to be done in SI units and quantities.

The ICRU defines the following.

"A *physical quantity* characterizes a physical phenomenon in terms that are suitable for numerical specifications"

"A *physical unit* is a selected reference sample of a quantity".

The NCRP (report 82 on the SI) notes:
"The magnitude of a specified physical quantity can be expressed as a product of a pure number and a unit and thus if the quantity is divided by its unit, a pure number is obtained."

Taking this one step further, one can only plot pure numbers on a graph, and thus the proper label for any graph axis is the quantity divided by the unit, *e.g.,* , "photon energy/MeV". I believe we should all strive to use this approach since it reduces confusion about what is being plotted.

On the course web page there is a link to a useful document about SI, "Some basic rules for use and writing of SI symbols and units". While looking at that, you may find "Writing Guidelines for Engineering and Science Students" is of interest via a link on the course page.

9 Known Changes in Schedule

None that I know of this term.

10 Course Outline

The following outline is quite ambitious given that we have at most 25 lecture periods which includes 2 term tests (so 23 lectures). The order will vary from what is below.

General introduction to radiotherapy and radiotherapy physics

Fundamental data for photons and electrons

Monte Carlo techniques of radiation transport: the fundamentals: intro EGSnrc, BEAMnrc

Structure of electron and photon external beams for radiotherapy and of dose distributions for brachytherapy sources.

Fundamental relationships in radiation dosimetry

Bragg-Gray and Spencer-Attix cavity theories

Derivation of the equations for air-kerma determination using a cavity ion chamber

Practical ion chamber dosimetry: ion chambers, electrometers, polarity, recombination, settling, chamber designs, charge collection vs voltage curve from low to high voltage

TG-51 protocol for external beam clinical dosimetry based on absorbed-dose standards

Dosimetry for non-standard reference conditions (small field or composite field dosimetry)

General intro to brachytherapy and the TG-43 protocol for dosimetry in brachytherapy.

General Cavity theory: photon detectors vs electron detectors.

Other forms of radiation detectors for radiotherapy:
TLDs
alanine
solid state devices (diodes, MOSFETS)
Fricke
radiographic and radiochromic films
scintillation detectors
OSL

Treatment planning
-DVHs, TCP, NTCP etc
-GTV, CTV, PTV etc definitions
-CT scans and what info one has
-defn of TPR, PDD, TMR, TAR -relationships between them
-dose calculations
-monitor unit calculations
-MC, superposition/convolution, older methods

Treatment techniques/delivery
-IMRT (MLCs and algorithms + info re leakage etc)
-IGRT

Proton Therapy

11 Learning Objectives

- to gain an overview of the radiotherapy process
- to become familiar with and understand the terminology used in radiotherapy physics
- to know cold the fundamental quantities (kerma, absorbed-dose etc) and interactions of radiation with matter
- to develop a deep understanding of the fundamentals or radiation dosimetry, with special emphasis on ion chamber dosimetry under reference conditions (TG-51, TG-61) and under non-standard conditions in small and/or composite fields.
- to become familiar with the general characteristics of many types of radiation detectors and their relative strengths and weaknesses
- to understand the physics behind the structure of dose distributions for photon beams, electron beams and brachytherapy sources

- to become familiar with the elements of Monte Carlo simulation as applied in radiotherapy applications
- to understand the TG-43 formalism for brachytherapy dosimetry and its limitations
- to understand the physics behind TARs, TPRs, TMRs, PDDs and the relationships between them
- to be able to perform a simple hand calc monitor unit calculation
- to understand the basic physics behind dose calculation algorithms for treatment planning and to understand the limitations of each
  - effective SSD
  - EqTAR
  - convolution/superposition
  - Monte Carlo
- to understand the basics of IMRT and IGRT, their benefits and limitations
- to become familiar with the elements of proton therapy, its pros and cons as well as new technologies being developed.

12 Assistance for Students

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/

13 Algonquin territory acknowledgement

We acknowledge that the land on which we gather and learn is the traditional and unceded territory of the Algonquin nation. You are invited to learn more (https://carleton.ca/indigenous/policies-procedures/algonquin-territory-acknowledgment/, reflect on how you can support anti-racism and decolonization, and take action. https://carleton.ca/indigenous/