PH5023 - Monte Carlo Radiation Transport Techniques

Credits: 15.0  Semester: 1  Number of Lectures:  
Academic Year: 2018-19

Lecturer: Dr Kenny Wood

Overview
This module introduces the theory and practice behind Monte Carlo radiation transport codes for use in physics, astrophysics, atmospheric physics, and medical physics. Included in the module: recap of basic radiation transfer; techniques for sampling from probability distribution functions; a simple isotropic scattering code; computing the radiation field, pressure, temperature, and ionisation structure; programming skills required to write Monte Carlo codes; code speed-up techniques and parallel computing; three-dimensional codes. The module assessment will be 100% continuous assessment comprising homework questions and small projects where students will write their own and modify existing Monte Carlo codes.

Aims & Objectives

Learning Outcomes
By the end of the lecture course students will have a comprehensive knowledge of Monte Carlo radiation transport techniques and applying them to write their own computer simulations for photon and neutron transport.

- Use random numbers to sample events and processes from probability distribution functions
- Understand and the structure of Monte Carlo radiation transfer codes for photon scattering and absorption
- Understand the structure of Monte Carlo codes for neutron transport including absorption, scattering, and fission
- Understand the concept of Monte Carlo detectors and estimators to determine physical quantities throughout a medium such as photon flux, fluence, radiation pressure
- Understand variance reduction techniques to improve signal-to-noise in Monte Carlo simulations: forced first scattering, weighting techniques, Russian roulette, next-event estimators
- Understand the structure of Monte Carlo codes for photon and neutron transport in three dimensional density structures
- Understand the structure of Monte Carlo codes for neutron criticality calculations
- Understand the important physical processes required for Monte Carlo simulations of light interacting with biological tissue, photobleaching, and photodynamic therapy
- Be able to write Fortran programs and subroutines to sample from probability distribution functions, both analytic and tabulated
- Be able to write Monte Carlo codes to simulate the transport of photons and neutrons in uniform density structures
- Be able to adapt and modify a publicly available three dimensional Monte Carlo code for specific problems in photon transport

Synopsis
Recap of basic radiation transport processes; introduction to Monte Carlo techniques for sampling from probability distribution functions; outline a simple isotropic scattering computer code. Scattering phase functions (electrons, molecules, dust, biological tissue); techniques for computing internal intensity moments; radiation force and pressure calculations. Techniques for improving signal-to-noise in simulations; weighting schemes; error analysis. Applications of Monte Carlo techniques for medical physics including fluorescence spectroscopy, photobleaching, photodynamic therapy. Application of Monte Carlo techniques for neutron transport and criticality calculations. Monte Carlo radiative equilibrium calculations for gas and dust. Monte Carlo photoionisation calculations. Other applications: radiation transfer through clouds & atmospheric physics; relativistic scattering; polarisation; radiation-hydrodynamics; cosmic ray transport; neutron transport. Fortran coding skills: basic mathematical functions; if statements; do loops; functions and subroutines; random number generators; iterative techniques. Parallelizing Monte Carlo codes.
Lectures on using and modifying publicly available Monte Carlo codes for scattering, radiative equilibrium, and photoionisation.

**Pre-requisites**
PH2012, plus at least one of: AS3013, PH3080, PH3081, PH3082.

**Anti-requisites**
None

**Assessment**
Coursework = 100% (first worksheet 25%, second worksheet 25%, class test 25%, computer based test 25%)

**Additional information on continuous assessment etc**
Please note that the definitive comments on continuous assessment will be communicated within the module. This section is intended to give an indication of the likely breakdown and timing of the continuous assessment.

This is a 15 credit module, so is expected to take 150 hours of study for the average student at this level. The module’s work is finished by revision week, so students can expect to commit about 14 hours a week to the module in weeks 1 to 11, including the hours scheduled in lectures and in the computing cluster. MPhys students are reminded that if they choose multiple “no-exam” modules then they will inevitably have a higher workload per week during weeks 1 to 11 than if they chose modules where some of the 150 hours was spent in the revision and exam weeks.

**Recommended Books**
Please view University online record:
http://resourcelists.st-andrews.ac.uk/modules/ph5023.html

**General Information**
Please also read the general information in the School’s honours handbook.