

# Electromagnetic Scattering I

Course page for Electromagnetic Scattering I – Sähkömagneettinen sironta I

The contents of the course are currently under further development. In autumn 2018, the course contained both single and multiple scattering, from the theoretical and computational point of view.

## Advanced Course, 5 credits, 53919, Autumn 2016, Period 1

The course Electromagnetic Scattering I offers an introduction and theoretical foundation for elastic electromagnetic scattering by arbitrary objects (usually called particles). As compared to the wavelength, the sizes of the objects can be small or large, or of the order of the wavelength. As to the shape of the objects, main emphasis is on spherical particles and, subsequently, on the so-called Mie scattering. The optical properties of the objects are typically described by the refractive index.

Course is held in Physicum, Tuesdays at 10-12 in D116 and Wednesdays at 10-12 in D106. Exercises are held Wednesdays at 14-16 in D106.

Lectures by Karri Muinonen, Johannes Markkanen, Antti Penttilä and Joonas Herranen (course assistant).

Recommended preliminary knowledge: basic courses in Physics, basic courses in Mathematics, Electrodynamics, Mathematical Methods for Physicists I & II, Scientific Computing I.

The scattering course starts by a review of classical electromagnetics introducing the Maxwell equations, the energy and impulse of electromagnetic fields, and Poynting's theorem. The wave equations are derived from the Maxwell equations and electromagnetic plane waves are discussed. The fundamentals of electromagnetism are followed by the necessary framework for classical scattering theory, defining the incident, internal, and scattered fields and the scattering plane as well as the scattering angle. The Stokes parameters and Mueller matrices are introduced. Thereafter, the  $2 \times 2$  amplitude scattering matrix and the  $4 \times 4$  scattering matrix are described.

The Fresnel reflection and refraction of electromagnetic plane waves on a plane interface are discussed as the first electromagnetic scattering problem, utilizing  $4 \times 4$  Mueller matrices for reflection and refraction. A treatment on scattering at long wavelengths follows, introducing the electric and magnetic multipoles and Rayleigh scattering, in particular. Particle shape is next taken into account in what is called the Rayleigh-Gans approximation. The scattering problem is presented in the volume-integral-equation formalism.

The rigorous treatment on electromagnetic scattering by spherical particles (Mie scattering) follows thereafter using multipole expansions. This involves the development of mathematical methods utilizing vector spherical harmonics. After Mie scattering, scattering at short wavelengths follows, relying partly on the reflection and refraction treatments in the early parts of the course. Main emphasis is however in diffraction of waves by obstacles, shedding light on Fraunhofer and Fresnel diffraction as well as on Kirchhoff integral relations between fields near the obstacles and the far fields. Towards the end of the course, the student will learn basics of computational methods for scattering by nonspherical particles, such as the discrete-dipole approximation and the T-matrix method.

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## Lecture material

- Handouts part [1](#), [2](#), [3](#), [4](#), [5](#), [6](#) by K. Muinonen, [7](#), [8](#), [9](#) by J. Markkanen, [10](#) by J. Herranen, [11-12](#) by A. Penttilä, [13](#), [14](#) by K. Muinonen

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## Exercises (return to mail slot of Herranen next to D308 or via e-mail)

- [Exercises 1](#)
- [Exercises 2](#)
- [Exercises 3](#)
- [Exercises 4](#)
- [Exercises 5 + material](#)

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## Background material

- P. C.Y. Chang, J.G. Walker, K.I. Hopcraft. [Ray tracing in absorbing media](#). JQSRT 96 (2005).

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## Suggested reading

- J. D. Jackson: Classical Electrodynamics
- C. F. Bohren & D. R. Huffman: Absorption and Scattering of Light by Small Particles
- M. I. Mishchenko, J. W. Hovenier & L. D. Travis: Light Scattering by Nonspherical Particles: Theory, Measurements, and Applications
- H. C. van de Hulst: Light Scattering by Small Particles

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Previous versions of this course

- [Autumn 2014](#)
- [Autumn 2012](#)

