PHYS30441 Physics with Theoretical Physics Core Unit
Prof. T. Wyatt. Physics Option Unit
Credit Rating: 10

PHYS30441 Electrodynamics (M) (C/O) SEM1

Prerequisites PHYS20141, PHYS20342

Very useful but not prerequisite PHYS20401

Follow-up units PHYS40481, PHYS40682, PHYS40771, PHYS40772

Classes 22 lectures in S6

Assessment 1 hour 30 minutes examination in January

Recommended texts

Griffiths, D.J., *Introduction to Electrodynamics* (Benjamin Cummings; 4th edition (2013)

Jackson, J.D., *Classical Electrodynamics* (John Wiley & Sons, 3rd edition 1999)

Supplementary reading

Feynman, R.P., *The Feynman Lectures on Physics, Vol II* (Addison Wesley, 1964)

Heald, M.A. & Marion, J.B. *Classical Electromagnetic Radiation*, (Academic Press, 1995)

Schwartz, M., *Principles of Electrodynamics* (Dover Publications, 1972)

Zangwill, A., Modern Electrodynamics (Cambridge University Press, 2013)

Rybicki, G.B. and Lightman, A.P., Radiative Processes in Astrophysics" (WILEY-VCH,2004)

Feedback

Feedback will be offered by examples class tutors based on examples sheets, and model answers will be issued. Some lecture sessions will provide extra problem-solving opportunities and cover a few interesting “extra-curricular” topics.

Aims

To cover theoretical aspects of electromagnetic fields and radiation, and their connection to special relativity.

Learning outcomes

On completion successful students will be able to:

1. use and explain: scalar and vector potentials; gauge invariance; compatibility of special relativity and electrodynamics; solutions to Poisson's equation and inhomogeneous wave equation;
2. use Lorentz covariant formalism (scalars, 4-vectors and tensors) in the context of electrodynamics and special relativity;.

3. distinguish between radiation fields and other electromagnetic fields; calculate the radiated power produced by accelerating charges.

Syllabus

1. **Revision and Preparation for More Advanced Material** (6 lectures and optional pre-recorded revision videos)

Definition of the scalar and vector potentials. Electrostatics and magnetostatics: Poisson's equation; multipole expansions. Maxwell's field equations. The inhomogeneous wave equations for the potentials and their solutions: the Lorenz gauge and retarded time. Index notation for vector calculus in 3-dimensions. Visualising retarded time: the appearance of objects moving at close to the speed of light. Revision of 1st year special relativity. Consistency of Maxwell's equations and special relativity.

2. **Special Relativity and Electrodynamics in Covariant Notation** (8 lectures)

Scalars, four vectors and tensors. Covariant and contravariant formalism of Lorentz transformations. Electrodynamics in covariant form: the 4-potential, 4-current and electromagnetic field tensor. 4-momentum and relativistic kinematics/dynamics. The stress-energy-momentum tensor: local conservation of 4-momentum.

3. **Radiation from Accelerating Charges** (6 lectures)

Lienard-Wiechert potentials. Informal and vector calculus derivations of the fields produced by an accelerating charged particle. Power radiated in the quasi-rest frame: Larmor radiation. Lorentz transformation of the angular distribution of radiated power: bremsstrahlung and synchrotron radiation.

4. **Harmonically Varying Sources** (2 lectures)

Multipole radiation: electric (Hertzian) and magnetic dipole radiation; slow-down of pulsars. Rayleigh and Thomson scattering.