PHYSICS 504        Spring 2023

ELECTRICITY & MAGNETISM II
(Tentative Syllabus)

This is a tentative schedule of what we will cover in the course. It is subject to change, often without
notice. These will occur in response to the speed with which we cover material, individual class
interests, and possible changes in the topics covered. Use this plan to read ahead from the lecture
notes and following textbooks, so you are better equipped to ask questions in class.


Special Relativity with basics of
relativistic Field Theory

- PRELIMINARIES

  **Space in Classical Physics:** Cartesian space. Euclidean structure. Curvilinear coordinates.
  Metric-preserving coordinate transformations. Translations of the origin. Proper and improper
  orthogonal transformations. Euler’s theorem. Isometries of $E^3$. Active and passive points of
  view.

  Suggested literature: Lecture notes
  
  - Secs.1.2.1-1.2.4,1.7 in [3]
  - Secs. 4.1-4.6 in [4]

  **Euclidean tensors:** Euclidean vectors and pseudovectors. Levi-Cevita symbol. Cross product.
  Tensors of rank two. Irreducible representations of $SO(3)$. Angular momentum addition. Parity
  transformations. Irreducible representations of $O(3)$.

  Suggested literature: Lecture notes
  
  - Secs. 1.2.5,1.8 in [3]
  - Secs. 4.7,4.8 in [4]

  **Spacetime in Classical Physics:** Event. Causal structure in classical spacetime. Inertial

  Suggested literature: Lecture notes
  
  - Sec.22.2 in [3]
• KINEMATICS OF SPECIAL RELATIVITY


Suggested literature: Lecture notes
$\S\S$1-3 in [1]
Sec. 11.1 in [2]
Sec.22.3 in [3]
Sec.7.1 in [4]

Lorentz group: Definition. Parity and time reversal transformations. Proper, improper, orthochronous, non-orthochronous Lorentz transformations. General structure of the Lorentz group. Lorentz boosts. Group of proper, orthochronous Lorentz transformations $SO^+(1, 3)$.

Suggested literature: Lecture notes
$\S\S$4,5 in [1]
Sec.11.2 in [2]
Sec.22.4 in [3]


Suggested literature: Lecture notes
$\S\S$6,7 in [1]
Secs.11.3,11.4,11.6 in [2]
Secs.22.5.1,22.5.2 in [3]

Matrix representations of the Lorentz group: Rank 2 antisymmetric tensor. Quadratic invariants. Finite dimensional irreducible representations of $SO^+(1, 3)$, $O^+(1, 3)$ and $O(1,3)$.

Suggested literature: Lecture notes

• COVARIANT FORM OF MAXWELL’S EQUATIONS

First pair of Maxwell’s eqs.: Fields. Field-strength tensor. Covariant form(s) of the first pair of Maxwell’s eqs.

Suggested literature: Lecture notes
$\S\S$23-26 in [1]
Secs.11.9,11.10 in [2]


Suggested literature: Lecture notes
$\S\S$23-25 in [1]
Secs.1.3,1.4,5.1-5.3,5.15,6.1,6.11,6.12 in [2]
Secs.1.4.2,1.2.2 in [3]

Second pair of Maxwell’s eqs.: Covariant form. 4-current. The continuity equation.

Suggested literature: Lecture notes
$\S\S$28-30 in [1]
Sec.1.5 in [3]


Suggested literature: Lecture notes
Sec.1.9 in [3]
**4-potential:** Definition. Bianchi identity. Maxwell’s equation in terms of the 4-potential. Gauge invariance. Gauge fixing condition. Lorenz gauge.

Suggested literature: Lecture notes

§18 in [1]
Secs.6.2.6.3 in [2]
Secs.15.3 in [3]

**VARIATIONAL PRINCIPLE**

**Poisson’s equation in curvilinear coordinates:** Variational principle for Poisson’s equation. Laplacian in curvilinear coordinates. Orthogonal coordinates.

Suggested literature: Lecture notes

Secs.1.7-1.12 in [2]

**Variational principle for Maxwell’s equations:** The principle of least action in relativistic Field Theory. Lagrangian density. Euler-Lagrange equations. The action functional of the electromagnetic field.

Suggested literature: Lecture notes

§§27,30,32 in [1]
Sec.12.7 in [2]
Secs.13.1,13.2 in [4]

**Maxwell’s equations in curvilinear coordinates:** Tensor fields in curvilinear coordinates. Differentiation. Exterior derivative. Divergency of a vector field. First pair of Maxwell’s equations in curvilinear coordinates. The action functional of the electromagnetic field in curvilinear coordinates. Lorenz gauge fixing condition in curvilinear coordinates.

Suggested literature: Lecture notes

§§81-83,90 in [1]


Suggested literature: Lecture notes

§§8,9,15 – 17 in [1]
Secs.6.7,12.1 in [2]
Secs.7.9,7.10 in [4]

**CONSERVATION LAWS**

**Symmetries:** Continuous and discrete symmetries of Classical Electrodynamics. Noether’s theorem.

Suggested literature: Lecture notes

Sec.6.10 in [2]
Secs.15.1,15.2,24.4.2 in [3]
Sec.13.7 in [4]


Suggested literature: Lecture notes

§§32,33,94 in [1]
Secs.6.7,12.10 in [2]
Secs.13.3,13.5,13.6 in [4]
Rotational invariance and angular momentum: 4-tensor of angular momentum. The center-of-energy theorem. Pauli-Lubanski 4-vector.

Suggested literature: Lecture notes
§§14, 32 in [1]
Secs.15.6,15.7 in [3]

Applications of Classical Electrodynamics

• MAGNETOSTATICS

Suggested literature: Lecture notes
§§43,44 in [1]
Sec.5.3-5.6 in [2]
Secs.11.1,11.2 in [3]

Macroscopic equations: Magnetization. The magnetic field (intensity). Boundary conditions. Relation between magnetic (field) induction and magnetic field (intensity). Methods of solving boundary value problems in magnetostatic.

Suggested literature: Lecture notes
Sec.5.8-5.13 in [2]

Simple magnetic matter: A magnetic moment in external magnetic field (the torque, the force, the potential energy). Larmor’s theorem. Diamagnetism. Paramagnetism. Curie’s law. Exchange interaction.

Suggested literature: Lecture notes
§§45 in [1]
Sec.5.7 in [2]

• QUASI-STATIC FIELDS

Suggested literature: Lecture notes
Sec.5.16,5.17 in [2]

Quasi-static magnetic fields in conductors: Quasi-static approximation. Skin effect.

Suggested literature: Lecture notes
Sec.6.3,5.18 in [2]
Secs.14.5-14.7, 14.10 in [3]

• ELECTROMAGNETIC WAVES
Waves in vacuum:
Waves in simple matter:
Waves in dispersive matter:

• RETARDATION AND RADIATION