# PHYSICS 504 Spring 2025

# ELECTRICITY & MAGNETISM II

## Midterm Exam

**Room:** ARC-204

**Time:** March 3, (Monday), 12:10-1:30 pm

## Ground rules

- There are four problems based on the material listed below.
- This is a closed book, closed notes exam.
- Partial credit will be given. Do as many parts of a problem as possible.

## Program

- **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 $\mathbb{E}^3$. 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. Matrix of finite rotations. Kronecker product. Tensors. Invariant tensors and pseudotensors. 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 frames. Galilean transformations. Galilean principle of relativity. Newton's first law.

  Suggested literature: Lecture notes
  Sec.22.2 in [3]

- **KINEMATICS OF SPECIAL RELATIVITY**

  **Spacetime in Special Relativity:** Causal structure in Special Relativity. Light cone. Space-time interval. Proper time. Pseudo-Euclidean (Minkowski) space $\mathbb{M}^{1,3}$. Einstein principle of relativity.

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

  **Tensors in the Minkowski space:** 4-velocity. Covariant and contravariant vectors. Tensors of rank 2. Metric tensor. Inner product in the Minkowski space. Tensors of higher rank in $\mathbb{M}^{1,3}$. Levi-Cevita symbol in $\mathbb{M}^{1,3}$. Pseudotensors.

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

  **Simple physics behind Maxwell's eqs:** Stokes's theorem. Faraday's law of induction. Monopoles. Gauss-Ostrogradsky theorem. Gauss's law. Ampère's law. Displacement current.

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

  **Differential $p$-forms:** Helmholtz's decomposition theorem. Definition of differential $p$-forms. Exterior derivative. Closed and exact forms. Poincaré lemma.

  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]

# Literature


[1] L D Landau and E.M. Lifshitz "The Classical Theory of Fields", Volume 2

[2] J.D. Jackson "Classical Electrodynamics" 3rd edition

[3] A. Zangwill, "Modern Electrodynamics", 1st edition

[4] H.Goldstein, C. Poole and J. Safko, "Classical Mechanics", 3rd edition