Information on the final exam

1 Basic Information

- Date and time: Thursday, January 15 at 9:15am
- Duration: 3 hours
- Location: SwissTech convention center
- You are allowed to bring one A4 cheat sheet (Writing both in the front and back is allowed).

2 Exam format

- The exam will consist of 35 multiple choice questions and 3 open questions. Each multiple choice question is worth 2 points and each open ended question 10 points (Total of 100 points). Note that NO points are subtracted for wrong answers.
- Questions will test both your conceptual understanding and your ability to to solve problems.

3 Review session for the exam

On December 8th: We will solve problems from last year's exam at our regular lecture time. During this time we will also address any other questions from the course.

4 Exam content

All material from Lectures 1 to 23 will be covered the exam. Similarly, you are expected to be able to solve all the types of problems covered in the exercise sheets. You will be tested both on your conceptual understanding and your ability to solve problems carrying out analytical calculations (i.e. you are expected to know how to apply different formulas and do the math). The entire semester we have been careful to define the units of all physical observables discussed (e.g. electric field, potential, magnetic field inductance, capacitance...), you are expected to know them and understand the physical interpretation of these observables with the help of dimensional analysis.

To help you study here is a list of the knowledge of the topics covered in each lecture you are expected to have, as well as the types of problems you are expected to know how to solve. You will see this is a summary of the content of the lectures and the exercise sheets.

1. **Review of vectors. The "del" operator.**
    - Understand the concept of a vector. Ability to perform operations with vectors (e.g. sum, multiplication by a scalar, dot product, curl).
    - Understand the geometrical interpretation of operations with the del operator, specifically the divergence, gradient and curl. Interpret the physical meaning of mathematical expressions involving the del operator.

- Ability to perform calculations and operations with the del operator (curl, divergence and gradient), in Cartesian and curvilinear coordinate systems (in particular cylindrical and spherical coordinates).

2. **Electric charge and Coulomb's law.**
   - Understand the concept and properties of electric charge.
   - Understand the mathematical definition and physical meaning of a continuous charge distribution (i.e. line, surface, volume charge densities). Ability to calculate total charge if charge distribution is given and vice versa.
   - Understand the physical implications that the electric force between two charged particles is proportional to $(1/r^2)$. Ability to make comparisons between the gravitational and electric forces.
   - Ability to apply Coulomb's law to determine the forces on charged particles and continuous charge distributions.
   - Ability to incorporate the principle of superposition in your calculations of electric forces on charged particles and continuous charge distributions.

3. **The electric field. Gauss's law and its applications.**
   - Understand the concept of the electric field and its properties.
   - Understand the concept and properties of field lines and equipotential lines. Ability to draw field lines for various charge distributions.
   - Ability to calculate electric fields for linear, surface, and volume charge distributions using Coulomb's law.
   - Understand the properties of conservative forces and the consequences of a force being conservative.
   - Understand the mathematical definition, geometrical and physical interpretation of flux. Ability to calculate flux of electric field through a surface.

4. **The Electric Potential. Gauss's law revisited.**
   - Ability to apply the divergence theorem to transition smoothly between integral and differential forms of equations.
   - Ability to use Gauss's law in differential form to determine the charge density that gives rise to an electric field.
   - Understand the physical meaning of the mathematical definition of the electric potential. Understand the relationship between electric field and electric potential.
   - Ability to calculate the electric field from the electric potential and viceversa.

5. **Poisson and Laplace's equations. The curl of E.**
   - Understand the implications of the uniqueness theorem for solution of Laplace's equation that represent the electric potential.
   - Understand the mathematical statement and geometric interpretation of Stokes's theorem.

6. **Conductors.**
    - Understand what is a conductor and what are its properties.
    - Ability to calculate the electric field in different regions of a conductor.
    - Ability to apply the method of images to solve problems involving conductors.
7. **Capacitors and Capacitance.**
    - Understand the concept of capacitance.
    - Understand why energy can be stored in capacitors.
    - Ability to calculate the capacitance of capacitors of different geometries.
    - Ability to calculate the energy stored in a capacitor.
    - Ability to calculate the equivalent capacitance in circuits involving capacitors.
8. **Multipole expansion. Dipole moments.**
    - Understand when is it appropriate to approximate the electric potential by a multipole expansion. Understand the concept of monopole and dipole moment.
    - Ability to calculate monopole and dipole moments for simple charge distributions.
    - Ability to calculate the forces and torques experienced by electric dipoles in external electric fields.
9. **Electric fields in matter I. Mechanisms of polarization. Bound charges.**
    - Understand the properties of dielectrics in general and the different types of dielectrics. Understand the concept of polarization.
    - Understand the physical origin and concept of surface bound charge and volume bound charge.
    - Ability to calculate the bound charge densities of a polarized dielectric.
    - Ability to calculate the electric field of a polarized material using the concept and equations related to bound charges.
10. **Electric fields in matter II. Electric displacement**
    - Understand the concept of electric displacement field.
    - Ability to calculate the electric (and electric potential) and polarization field using the definition of displacement field.
    - Ability to calculate the displacement field using its definition.
    - Ability to calculate the displacement field using Gauss's law for systems with symmetry.
    - Ability to sketch $\mathbf{E}$, $\mathbf{P}$ and $\mathbf{D}$.
    - Understand the behavior of dielectrics in capacitors.
    - Ability to calculate the forces acting on a dielectric inside a capacitor.
11. **Electric currents and Ohm's Law.**

- Understand the concept of electric current and the continuity equation.
- Ability to use the microscopic form of Ohm's law to calculate current densities and drift velocities of electrons.
- Ability to use the macroscopic form of Ohm's law to solve circuits.

12. **Electromotive force. Circuits and Kirchhoff's Rules.**
    - Understand the concept of electromotive force in the context of electric circuits.
    - Ability to apply Kirchhoff's rules to solve circuits involving resistors and capacitors (e.g. calculate currents and voltage drops across elements).
    - Understand the process and equations that describe the charging and discharging of capacitors.
    - Ability to solve problems related to charging and discharging capacitors.
13. **Magnetostatics I. Lorentz force.**
    - Understand the concept of magnetic force and magnetic field.
    - Ability to use Lorentz force law to calculate the trajectory, velocity or mass of a charged particle in a magnetic field.
    - Understand why magnetic forces do no work.
    - Ability to calculate forces and torques on current loops with diverse geometries in external magnetic fields.
14. **Magnetostatics II. Biot-Savart and Ampere's laws.**
    - Understand the concept of a steady current.
    - Understand the mathematical definition and physical meaning of a continuous current distribution (i.e. line, surface, volume current densities).
    - Ability to use the Biot-Savart's law to calculate magnetic fields of arbitrary steady current distributions.
    - Ability to use Ampere's Law to calculate magnetic fields of symmetric current distributions.
15. **Magnetic vector potential.**
    - Understand the concept of magnetic vector potential.
    - Ability to calculate the magnetic vector potential of a current distribution.
    - Ability to calculate the magnetic dipole moments of loops of current of different geometries.
16. **Magnetic Fields in matter I. Mechanisms of magnetization. Bound currents.**
    - Understand the types of magnetic materials and their properties.
    - Understand the concept of magnetization.
    - Ability to calculate the magnetic fields and potentials of magnetized materials.

- Understand the concept of bound currents.

17. **Magnetic fields in matter II. The auxiliary Field H.**
    - Ability to calculate magnetic fields using the auxiliary field **H** and Ampére's law.
    - Understand the concept of hysteresis in ferromagnetic materials.
18. **Electromagnetic Induction. Faraday's law of induction.**
    - Understand the concept of electromagnetic induction.
    - Understand the concept of magnetic flux.
    - Ability to use the concept of magnetic flux to calculate motional emfs.
    - Understand the physical interpretation of Lenz's law.
    - Ability to use Lenz's Law to determine the direction of induced currents.
    - Ability to use Faraday's Law to calculate induced emfs.
19. **Inductance and magnetic energy.**
    - Understand the concepts of self and mutual inductance.
    - Understand why energy can be stored in inductors.
    - Ability to calculate the inductance for inductors of different geometries.
    - Ability to calculate the energy stored in an inductor.
    - Ability to solve circuits involving inductors using Kirchhoff's rules.
20. **Alternating current circuits.**
    - Ability to solve alternating current circuits.
    - Ability to draw a phasor diagram for an alternating current circuit.
21. **Maxwell's equations.**
    - Understand the concept of displacement current and its role in Maxwell's addition to Ampere's Law.
    - Ability to explain the physical meaning of all of Maxwell's equations.
    - Understand why Maxwell's equations imply the existence of electromagnetic waves.
22. **Electromagnetic waves.**
    - Understand the properties of electromagnetic waves.
    - Ability to calculate the electric and magnetic fields associated with electromagnetic waves.
    - Understand the concept and types of polarization of electromagnetic waves.
23. **Energy and momentum of electromagnetic waves.**
    - Understand of the physical meaning of the Poynting vector.

- Ability to calculate the Poynting vector for electromagnetic waves and its associated electric and magnetic fields.
- Ability to use the Poynting vector of an arbitrary electric field and magnetic field configuration to understand energy flux in the system.