PLASMA PHYSICS
Corso di Laurea Magistrale in Ingegneria Energetica / Energy Engineering
prof. Stefano Atzeni and prof. Angelo Schiavi
A.A. 2016-2017

Materials:
- Lecture notes and presentations available on http://gaps.ing2.uniroma1.it/atzeni/ (click on "didattica")
- Short portions of S. Atzeni and J. Meyer-ter-Vehn, The Physics of Inertial Fusion, Clarendon-Oxford, 2004.
- Two useful additional texts:
  R. J. Goldstone and P. H. Rutherford, Introduction to Plasma Physics, Taylor & Francis, 1995
  G. Pucella e S. E. Segre, *Fisica dei Plasmi*, Zanichelli, Bologna, 2010 (in Italian)

Definition of plasma. Collective effects. Natural and artificial plasmas
- Saha equation for ionization equilibrium
- Debye shielding and quasi-neutrality. Debye length
- Plasma oscillations and plasma frequency: double layer model and
   fluid model
- Ideal and correlated plasmas, classical and quantum plasmas
- Natural and man-produced plasmas. Characteristic parameters

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Charged particle motion in external electric and magnetic fields. Drifts.
- Uniform magnetic field: Larmor radius, cyclotron frequency
- Uniform electric and magnetic fields: $E \times B$ drift
- Non uniform magnetic field:
  - grad B orthogonal to B (grad B drift)
  - curvature drift
  - grad B parallel to B: first adiabatic invariant
- Examples: magnetic mirror; need for "rotational transform" in toroidal
     configurations

Coulomb collisions
- Collisions in center of mass system
- Collision parameter, scattering angle
- Rutherford cross-section
- Collision frequencies, mean-free-paths
- Relaxation times and energy equilibration times
- Electrical resistivity: collisional model; runaway electrons

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Radiation emission
- General aspects. Larmor formula
- Cyclotron radiation
- Bremsstrahlung

Plasmas and controlled nuclear fusion. Principles
- Fusion reactions, cross sections, reactivity
- Main reactions between hydrogen isotopes (DD, DT)
- Thermonuclear fusion
- Steady-state power balance of a thermonuclear plasma:
  ideal ignition temperature, Lawson criterion, $n\tau T$ criterion
- Principles of main confinement schemes (magnetic and inertial)

Simple applications of MHD
- Magnetic field diffusion
- B lines freezing
- Fluid drifts orthogonal to B
  - Diamagnetic drift and diamagnetic current
  - $E \times B$ drift

Particle and energy transport
• Classical treatment of diffusion coefficient
• Diffusion coefficient for magnetized and unmagnetized plasma
• Discussion: anomalous transport

Plasma waves
• Wave equation and wave solutions; group and phase velocity
• Linear perturbation theory and dispersion relation
• Waves in a fluid plasma. Linear theory. Electrostatic and electromagnetic waves.
• Electron plasma waves (Bohm-Gross waves)
• Electromagnetic waves in unmagnetized plasmas
o Dispersion relation. Cut-off and critical density.
o Collisional absorption (with application to laser-plasma interaction)
o Basic concepts on plasma created by the interaction of an intense laser pulse with a solid: ablation, ablative pressure. Application to inertial confinement fusion: ablation-driven implosion
• Basic concepts on parametric processes
• Alfvén waves

MHD equilibrium
• General remarks. Orthogonality between B lines and pressure gradient, and between current lines and pressure gradient; magnetic surfaces, current tubes.
• Principles of Zeta- and Theta-pinch.

Introduction to Inertial Confinement Fusion
• Essential requirements: compression and hot-spot ignition
• Laser-driven inertial confinement. Direct and indirect drive.
• Estimate of main parametes
• Key physics issues
• Notions on lasers for fusion

Introduction to Magnetic Confinement Fusion
• Close and open configurations
• Toroidal configurations. Toroidal field, poloidal field, vertical field. Tokamak and Stellarator.
• Main elements of a tokamak.
• Key physics issues

[last updated: February 17, 2017]

S. Atzeni
Dipartimento SBAI, Ed. RM009
Via A. Scarpa, 14
stefano.atzeni@uniroma1.it
gaps.ing2.uniroma1.it/atzeni/

A. Schiavi
Dipartimento SBAI, Ed. RM009
Via A. Scarpa, 14
angelo.schiavi@uniroma1.it
gaps.ing2.uniroma1.it/schiavi/