RADIATIVE PROCESSES in ASTROPHYSICS

Exam
The exams will consist of two questions from the list below plus 1-2 problems which will be similar to those solved at home. No help from the books, lecture notes, or any other material is allowed during the exam. You are allowed to take one A4 page with you on the exam. A calculator maybe needed. The answers to the first two questions should contain, e.g., the derivation of some formulae (if that is asked for) and a short physical description of what the formula and its different terms mean. There is no need to write a long essay on the topic of the question.

Questions

1. Basics of radiative transfer: definitions of intensity, mean intensity, flux, radiation pressure, energy density, relations between some them. Absorption and emission coefficients. Radiative transfer equation and its formal solution.


3. Scattering. Mean free path, random walk, mean number of scatterings, escape time.

4. Combined effects of scattering and absorption. The source function, mean free path, thermalization length, and the effective optical thickness.


6. Definitions of electric and magnetic fields. Lorentz force. Work performed by the field on charges and per unit volume.


13. Inhomogeneous wave equation for \( \phi \) and \( \vec{A} \). Green’s function method. Heuristic solution of equation
\[
\Box^2 G(\vec{x}, t; \vec{x}', t') = -4\pi \delta(\vec{x} - \vec{x}', t - t')
\]
Retarded potentials.


15. Electromagnetic potentials and Poynting flux in wave zone.


23. Electromagnetic field from accelerated charge in the wave zone. Given the general expression for the received power (5.56), derive formulae for the received power in two special cases: velocity parallel and perpendicular to acceleration. Make a picture of the radiation pattern in these cases, explain.

24. Difference between received and emitted power. Power emitted by a relativistic charge.


26. The approximate form of the bremsstrahlung spectrum. Temperature and density dependences of the emission coefficient and cooling rate. Derivation of the absorption coefficient via Kirchhoff’s law. Typical spectra from HII regions.

28. Magnetobremsstrahlung (synchrotron and cyclotron radiation). Total emitted power by a relativistic charge in magnetic field. Express it via magnetic field energy density, electron Lorentz factor, pitch angle. Emitted power for isotropic distribution of particles. Definition of cooling time, typical cooling times for different astrophysical objects, compare them to the crossing times.

29. The spectrum of synchrotron radiation of monoenergetic relativistic charge, qualitative discussion. The low energy slope and the peak frequency. The spectrum of synchrotron radiation for a power-law electron distribution.

30. Synchrotron self-absorption for thermal vs. non-thermal (power-law) electron distribution. The slope of the self-absorbed part of the spectrum.


33. Compton scattering. Relation between frequencies of the incident and scattered photons. Typical energy gain due to scattering of isotropically distributed photons on relativistic electrons.

34. Compton scattering. Total power emitted by an electron in the isotropic soft photon field. Analogy with the synchrotron radiation formula. Competition between synchrotron and Compton losses.


36. Non-relativistic Compton scattering. Mean energy gain of photon per scattering for monoenergetic and Maxwellian electrons. Multiple scattering: mean number of scattering N, total relative energy change after N scatterings. The concept of Compton (Kompaneets) y-parameter.