Autumn 2022, 578B Physical kinetics, TTh 9:30-10:50, Instructor Boris Spivak, office B440.

This is a special topic course on kinetics. The content of the course is clear from the list of topics below. I will discuss paradigms of the physical kinetics which can be frequently seen across different areas of theoretical physics. Roughly speaking the first part of the course will correspond to two books of L.D. Landau and E.M. Lifshitz Fluid mechanics, and E.M. Lifshitz L.P. Pitaevskii, Physical kinetics. In the second part of the course I am planning to use reviews on different subjects.

The course is aiming at students with a variety of backgrounds .

Grading: C/NC.

There will be no final exam. Students will be judged by bi-weekly HW.

I will use the following books :

L.D. Landau, E.M. Lifshitz, Physical kinetics,

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A.A. Abrikosov, Fundamental of the theory of metals,

I.M. Khalatnikov, The introduction to the theory of superfluidity,

and reviews on different subjects.

A TENTATIVE PLAN OF THE COURCE:

I. FLUID MECHANICS.

A. Ideal fluid, 2 lectures.

1. The continuity and Euler's equations, Energy and momentum fluxes. Sound waves in compressible fluids. Do sound waves transfer mass?
2. Incompressible fluids. Gravity waves. Characteristics and Reimann's invariants, Shock waves. Shallow water theory, Korteweg-De Vries equation, and solitons.

B. Viscous fluids. 1 lecture.

1. The equations of motion of a viscous fluid. Second viscosity.
2. Classical corrections to hydrodynamics and breakdown of classical hydrodynamics in 1d.

C. Turbulence. 2 lectures.

1. Several scenario of transition to strong turbulence: quasi-periodic flow and frequency locking, strange attractors, transition to turbulence by period doubling.
2. Fully developed turbulence, Kholmogorov's spectrum.
3. The relation between the lift and the fluid circulation (Zhukovskii's theorem.)

D. Magnetic fluid dynamics. 1 lecture.

1. Equation of motion of fluids in magnetic field. Magneto-hydrodynamic waves: van Alfven waves and magneto-sound waves.
2. Frozen magnetic field in conducting fluids. Spontaneous magnetic field in turbulent fluid (magnetic dynamo) and origin of cosmic magnetic field.

E. Relativistic fluid hydrodynamics. 1 lecture

F. Superfluid hydrodynamics. 1 lecture.

II. CLASSICAL KINETICS.

A. Weakly interacting particles. (Gases, Fermi liquid.) 2 lectures.

1. Many particle and single particle distribution function. Boltzmann kinetic equation in centro-symmetric and non-centrosymmetric media. A role of Barry phase and topology in quasi-classical kinetic equation. .
2. Derivation of Navier-Stoks equations and the diffusion equations.
3. Kinetics of electron-photon system in astrophysics and Zeldovich-Sunyaev effect.

B. Kinetic theory of plasma. 1 lecture.

1. Ambipolar diffusion.
2. Collisionless plasma. Plasma waves, linear and nonlinear Landau damping.

C. Theory of weak plasma turbulence, collapse of the weak turbulence. 1 lecture.

D. Phonon transport in dielectrics. 1 lecture.

E. Electron kinetics in metals. 2 lectures.

1. derivation of kinetic coefficients.
2. Galvano-magnetic effects.
3. Normal and anomalous skin effects.
4. Heliclal and magneto-plasma waves in metals.

III. ELECTRON TRANSPORT IN SUPERCONDUCTORS. 3 LECTURES.

1. Kinetic coefficients (conductivity, thermal conductivity, thermoelectric effects etc.)
2. Pinning of the flux lattice in superconductors and the flux flow.

IV. QUANTUM KINETICS. 4 LECTURES.

A. How to calculate transport properties if systems are strongly correlated and the Fermi liquid theory is violated? Luttinger method. 1 lecture.

B. Weak localization and mesoscopic effects in metals. 2 lectures.